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ABSTRACT

This unit is a basic introduction to entomology. The instructor guide and the corresponding student reference contain seven lessons: (1) introduction to entomology; (2) insect collection; (3) insect identification; (4) methods of control; (5) chemical control measures; (6) safe use of insecticides; and (7) integrated pest management. Students learn basic concepts in this unit by applying them in a practical manner. Making an insect collection and completing an insect fact sheet enables students to compare insects. The instructor guide includes transparency masters, job sheets, activity sheets, work sheets, a butterfly model and Appendix A, information on calibrating sprayers. For ease of use, performance objectives and competencies are included at the beginning of the unit, as well as being incorporated within each lesson. Eighty-eight references are listed. A competency profile is provided for recordkeeping. A glossary of terms used in entomology and insect control is included in the student reference. (NLA)

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MISSOURI AGRICULTURAL EDUCATION

10-6100-I

Entomology

for Agricultural Science II
Core Curriculum

ED329216

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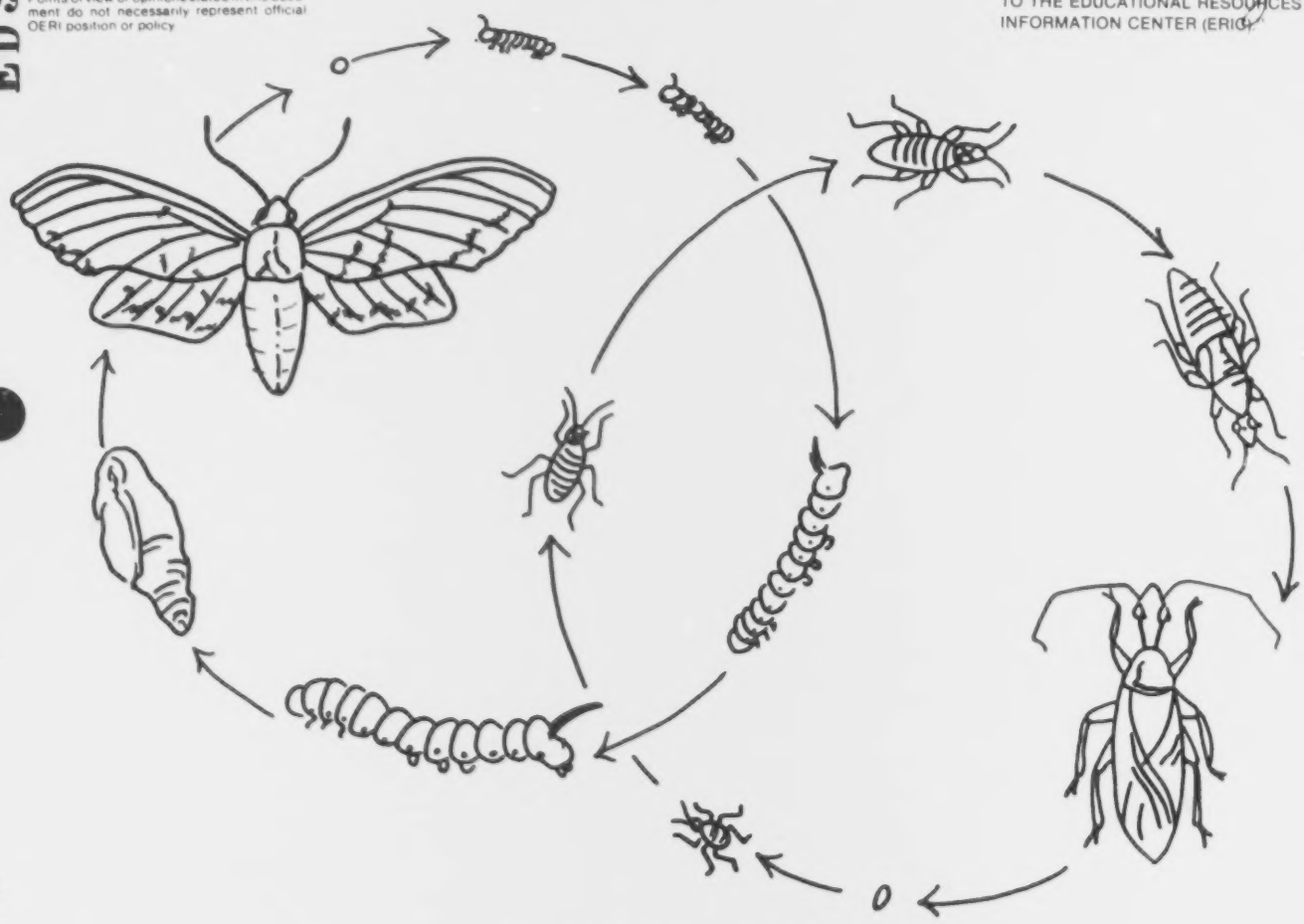

Instructor Guide

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Department of Practical Arts
and Vocational-Technical Education
College of Education and College of Agriculture
University of Missouri-Columbia

In cooperation with
Agricultural Education Section
Division of Vocational and Adult Education
Department of
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ENTOMOLOGY

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ACKNOWLEDGMENTS

Recognition is given to advisory committee members for providing their valuable time and suggestions in developing this unit. The committee consisted of Ray Hasenjaeger, Flernoy Jones, Don Kabel, Delbert Lund, Wes Miller, Jim Russell, Ron Scheiderer, Ed Stephens, and Jim Welker.

Special recognition is given to Carol Anderson of Osage Beach, Missouri for illustrating this unit.

Appreciation is expressed to the following staff members of the Instructional Materials Laboratory for their efforts in producing this material: Harley Schlichting, Director; Amon Herd, Associate Director; Phyllis Miller, Assistant Director; Dan Stapleton, Assistant Director; and Lori Holliday, Word Processor.

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FOREWORD

The development of the Entomology unit is the result of suggestions by the MVATA Teaching Aids Committee. The Entomology Advisory Committee suggested the topics to be discussed and reviewed the materials. Although this unit is designed to be taught as part of the Agricultural Science II Core Curriculum, it could be used to supplement any advanced agricultural course.

This unit is a basic introduction to the world of entomology. This instructor guide and the corresponding student reference contain seven lessons: Introduction to Entomology, Insect Collection, Insect Identification, Methods of Control, Chemical Control Methods, Safe Use of Insecticides, and Integrated Pest Management. Transparency masters, job sheets, activity sheets, and work sheets have been included where appropriate. For spreading practice, a butterfly model has been included as Demonstration Sheet 2.1. It is suggested that the model be cut out of cardboard or some other stiff paper. Appendix A includes information on calibrating sprayers.

Students are better able to learn and remember basic concepts if they can be applied in a practical manner. Making an insect collection will enable students to compare insects. Each student will also be completing an insect fact sheet for one particular insect. The fact sheet will be started in Lesson 3 and completed throughout the remaining lessons as the student learns more information about insects. These activities will enable students to apply the concepts learned, thereby making the materials more meaningful.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, Dr. Frank Drake, Director of Vocational Education, applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning.

This guide incorporates the needed component parts to aid agriculture teachers in the implementation of VIMS. For ease of use, performance objectives and competencies have been included at the beginning of the unit, as well as being incorporated within each lesson. A competency profile has been provided for convenient record keeping.

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ENTOMOLOGY

TABLE OF CONTENTS

ACKNOWLEDGMENTS ii

FOREWORD iii

COMPETENCY PROFILE ix

Lesson 1--Introduction to Entomology 1
Lesson 2--Insect Collection 13
TM 2.1: Location of Insects
TM 2.2: Killing Jar
TM 2.3: Mounted Insects and Labels
TM 2.4: Pin Placement for Different Insects
TM 2.5: Pinning Blocks
TM 2.6: Spreading Board
TM 2.7: Spreading an Insect
DS 2.1: Butterfly Model
JS 2.1: Making a Killing Jar
JS 2.2: Labeling Insects
JS 2.3: Spreading the Wings of Butterflies and Moths
AS 2.1: Making an Insect Collection
Lesson 3--Insect Identification 45
TM 3.1: Three Main Sections of an Insect
TM 3.2: Types of Antennae
TM 3.3: Types of Mouth Parts
TM 3.4: Types of Insect Legs
TM 3.5: Examples of Wings
TM 3.6: Stages of Development
TM 3.7: Incomplete Metamorphosis
TM 3.8: Complete Metamorphosis
TM 3.9: Insect Classification
HO 3.1: Systematic Method to Identify Insect Orders
WS 3.1: Insect Fact Sheet
WS 3.2: Insect Orders
Lesson 4--Methods of Control 81
Lesson 5--Chemical Control Methods 89
Lesson 6--Safe Use of Insecticides 97
WS 6.1: Reading an Insecticide Label
Lesson 7--Integrated Pest Management 109
Appendix A--Calibrating Sprayers 117

OBJECTIVES

1. The student will be able to discuss the significance of entomology.

2. The student will be able to prepare an insect collection.

3. The student will be able to describe the procedure for classifying insects to order.

4. The student will be able to describe methods of pest control.

5. The student will be able to describe the factors in the selection and application of insecticides.

6. The student will be able to identify safety guidelines for insecticide use.

7. The student will be able to outline an IPM plan.

COMPETENCIES

1. Discuss the significance of entomology.

2. Prepare an insect collection.

3. Describe the procedure for classifying insects to order.

4. Describe methods of pest control.

5. Describe the factors in the selection and application of insecticides.

6. Identify safety guidelines for insecticide use.

7. Outline an IPM plan.

REFERENCES AND MATERIALS

1. Student Reference

   Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.

2. Teacher References

   a) Books

      1) Apply Pesticides Correctly. Washington, DC: United States Department of Agriculture. U.S. Government Printing Office, 1975.

      2) Bland, R.G. How to Know the Insects. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

      3) Borror, D.J. and R.E. White. A Field Guide to the Insects. Boston, MA: Houghton Mifflin Company, 1970. (Available from the Instructional Materials Laboratory, 10 London Hall, Columbia, MO 65211.)

      4) Boyd, E.M. Toxicity of Pure Foods. Cleveland: CRC Press, 1973.

      5) Evans, Howard E. INSECT BIOLOGY: A Textbook of Entomology. Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

6) Greenhouse Operation and Management. University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

7) Guidelines for Insecticide Use. Lexington, KY: University of Kentucky, Department of Entomology, 1989.

8) Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington DC: United States Department of Agriculture. U.S. Government Printing Office, 1982.

9) Insect Control Recommendations. University of Missouri-Columbia: University Extension, 1990. (Available from the Instructional Materials Laboratory, 10 London Hall, Columbia, MO 65211.)

10) Pest Management Strategies in Crop Protection, Washington, DC: Congress of the United States. Office of Technology Assessment.

11) Peters, Leroy L. 4-H Entomology Project. University of Missouri-Columbia: University Extension, 1981.

12) Peters, Leroy L., ed. 4-H Entomology (Leader's Guide). University of Missouri-Columbia: University Extension.

13) The Random House Encyclopedia. New York, NY: Random House, Inc., 1977.

b) University Extension agricultural guides: University of Missouri-Columbia

1)	MP0517	A Pictorial Field Key to Wireworms Attacking Corn in the Midwest
2)	G04566	Alfalfa Insect Scouting
3)	G07392	Ants
4)	G04561	Aphid Control in Alfalfa
5)	G07011	Beef Cattle Lice Control
6)	PS0025	Beneficial Insects
7)	G04569	Blister Beetles in Alfalfa
8)	G07360	Boxelder Bugs
9)	G07175	Cabbage Pest Management
10)	G07423	Carpenter Ants
11)	G07424	Carpenter Bees
12)	G07414	Cigarette Beetle and Drugstore Beetle
13)	G07358	Clover Mites
14)	G07384	Cockroaches
15)	PS0008	Common Forage Legume Insects
16)	PS0010	Common Fruit Insects
17)	G02430	Common Internal Parasites of Swine
18)	PS0007	Common Small Grain Insects
19)	PS0006	Common Soybean Insects
20)	PS0009	Common Vegetable Insects
21)	G04565	Control of the Variegated Cutworm and Fall Armyworm in Alfalfa
22)	G04154	Control of Wireworms and Other Corn Soil Insects
23)	G07020	Controlling External Parasites of Swine
24)	G07255	Controlling Insect Carriers of Dutch Elm Disease and Elm Phloem Necrosis
25)	G06206	Controlling Insect Pests in Home Gardens
26)	G04560	Controlling the Alfalfa Weevil

27) G04150 Corn Cutworm Control
28) PS0004 Corn Insects - Above Ground
29) G04151 Corn Rootworm Control
30) G04252 Cotton Insect Control
31) PS0012 Cotton Insects and Mites
32) G07356 Elm Leaf Beetle
33) RP0327 European Corn Borer Development and Management
34) G07380 Fleas
35) G07388 Fly Control in and Around the House
36) G07030 Fly Control in Caged Layer Buildings
37) G07001 Fly Control in Dairy Buildings
38) G07010 Fly Control on Beef Cattle
39) G07000 Fly Control on Dairy Cattle
40) G07374 Indian Meal Moth and Angoumois Grain Moth
41) MP0619 Insect Pests of Horses in Missouri
42) G07012 Making and Using a Cattle Backrubber
43) G04559 Making Decisions For Controlling the Potato Leafhopper in Alfalfa
44) MX0003 Missouri Insect Control Recommendations
45) PS0005 Mo. Corn Insects - Below Ground
46) SB0738 Poisonous Spiders
47) PS0001 Principal Stored Grain Insects
48) G07376 Saw-toothed Grain Beetle, Confused Flour Beetle and Red Flour Beetle
49) G04906 Soil Insect Control in Reduced Tillage Cropping Systems
50) G04349 Sorghum Aphid Pest Management
51) G07362 Sowbugs, Pillbugs, Millipedes and Centipedes
52) PS0028 Stored Grain Insects and Molds
53) G07555 Submitting Insect and Mite Specimens for Identification
54) G07420 Termites
55) G07250 The Bagworm in Missouri
56) G04564 The Meadow Spittlebug in Alfalfa and Red Clover
57) G07251 The Mimosa Webworm in Missouri
58) G04562 The Potato Leafhopper in Alfalfa
59) PS0020 Tobacco Insects: An Aid to Identification and Control
60) G01195 Walk-Through Trap to Control Horn Flies on Cattle
61) G07422 Wood-Damaging Beetles
62) EP0014 Yellowjackets, Hornets, and Paper Wasps

c) Audiovisual materials available from the Instructional Materials Laboratory, 10 London Hall, Columbia, MO 65211.

1) Entomology Identification - slides
2) Insect Identification and Control Series - slides
-Household Insects: Identification & Control
-Turf Insects: Identification & Control
-Vegetable Insects: Identification & Control
-Shade Tree & Woody Shrub Insects: Identification & Control

d) Audiovisual materials available from the Missouri Vocational Resource Center (MVRC), 8 London Hall, Columbia, MO 65211.

1) Identifying Common Insect Pests - slides
2) IPM Video Series - 3 videos
-Integrated Pest Management in Horticulture

-Greenhouse Integrated Pest Management
-IPM in Agriculture

3) Managing the Environmental Impact of Pesticides - slides
4) Pesticide Application: Equipment and Calibration - slides
5) Pesticides in Agriculture - video
6) Reading Chemical Container Labels - slides
7) Safe Use of Pesticides Around the Home - slides
8) Using Farm Chemicals Safely - slides

ENTOMOLOGY
Major Competency Profile

Directions: Evaluate the student by checking the appropriate number or letter to indicate the degree of competency. The rating for each task should reflect **employability readiness** rather than the grades given in class.

Rating Scale: **3 Mastered** - can work independently with no supervision
2 Requires Supervision - can perform job completely with limited supervision
1 Not Mastered - requires instruction and close supervision
N No Exposure - no experience or knowledge in this area

3	2	1	N	UNIT - ENTOMOLOGY
				1. Discuss the significance of entomology.
				2. Prepare an insect collection.
				3. Describe the procedure for classifying insects to order.
				4. Describe methods of pest control.
				5. Describe the factors in the selection and application of insecticides.
				6. Identify safety guidelines for insecticide use.
				7. Outline an IPM plan.

_____

_____

Entomology

Class/Section: _____

Students:

	1. Discuss the significance of entomology.
	2. Prepare an insect collection.
	3. Describe the procedure for classifying insects to order.
	4. Describe methods of pest control.
	5. Describe the factors in the selection and application of insecticides.
	6. Identify safety guidelines for insecticide use.
	7. Outline an IPM plan.

x

UNIT - ENTOMOLOGY

Lesson 1: Introduction to Entomology

Objective: The student will be able to discuss the significance of entomology.

Study Questions

1. **What is entomology?**
2. **Why is entomology important?**
3. **What is the role of insects in society?**
4. **What are the educational requirements of some careers in entomology?**
5. **What are some career areas enhanced by a working knowledge of entomology?**

References

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.
2. Handout
   a) HO 1.1: Facts About Insects
3. Work Sheet
   a) WS 1.1: Interview

UNIT - ENTOMOLOGY

Lesson 1: Introduction to Entomology

TEACHING PROCEDURES

A. Introduction

Outline the lessons to be discussed.

B. Motivation

1. Distribute HO 1.1, a list of "fun facts" about insects and entomology. Discuss how entomology affects our lives. To help students relate insects to their lives, ask questions such as "Why is food cooked?" or "Why is food stored at certain temperatures?".

2. Break down a common product into its basic components. Point out the different careers involved in the production of the product. Also point out how entomology is involved in those careers.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students what entomology is. Explain that insects are small, six-legged animals. Emphasize the extensive insect activities in the world and in our lives.

What is entomology?

Entomology is the study of insects. The study of insects includes their development, anatomy, physiology, life history, behavior, environment, and classification.

2. Discuss why entomology is important. Point out that insects can have a positive or negative effect on plants, people, and the environment.

Why is entomology important?

a) Insects are the most numerous animals in the world.
b) They have an enormous impact on people's lives.
c) Entomology gives people a better understanding of the environment, biology, and the world in which they live.
d) Entomology can be used to help reduce the extensive economic losses in damage caused by insects each year.
e) Entomology helps improve human and animal health.

3. Discuss how insects are involved in different industries. Encourage students to think of ways in which insects are beneficial and harmful.

What is the role of insects in society?

a) Agriculture

1) Agriculture is a major industry in the U. S. and the world.
2) Insects play an important part in the food chain by providing food for other animals.
3) Some insects destroy other insects that are considered harmful.
4) Insects pollinate crops.
5) Insects damage or destroy crops, food and fiber products, and wood.
6) Insects provide food (honey from the honey bee) and fiber (silk from the silk worm).

b) Environmental sciences - the study of the forces and conditions that surround and influence living and nonliving things; includes any studies in ecology
1) Insects break down organic and nonorganic materials in the environment. Insects are nature's own recycling program.

c) Medicine
1) Insects transmit diseases to humans, animals, and plants.
2) Insects are used extensively in many kinds of research because of their small size and rapid reproduction.

d) Construction
1) A knowledge about insects is used when selecting the type of construction material.
2) Insects, such a termites, can cause damage to wooden structures.

e) Product development - insects used in the research and development of products such as cosmetics, cleaning materials, food preservatives, and medicines

4. Discuss how studying insects can lead to many different career choices. Entomologists are scientists who specialize in the study of insects. A wide variety of careers are available. These careers require different levels of education and training. Entomologists can be grouped by their area of specialization, and these areas often overlap. Have students interview someone who uses entomology directly or indirectly in his or her work. Students should use WS 1.1 as an outline when conducting the interview.

What are the educational requirements of some careers in entomology?

a) Agricultural entomologists
1) Study insects that affect the production of foods and fibers
2) Work in all industries in agriculture
3) Educational requirements vary from some training in entomology to a doctoral degree in entomology.
4) Examples of careers in this area include: crop scout, agricultural product dealer, insecticide applicator, researcher, forester, greenhouse manager, pest controller.

b) Entomology instructors
1) Teach entomology at different levels (high school, junior college, and university)
2) Educational requirements will vary depending on job

c) Medical and veterinary entomologists
1) Are concerned with insects that influence the health of people and animals in any way
2) Develop insecticides to protect crops and reduce diseases
3) Many jobs require a graduate degree in the area of medical specialization with additional training or classes in entomology. Some jobs may only require a two-year degree.
4) Include doctors, assistants, and technicians

e) Industrial entomologists

1) Involves the research and manufacture of many types of products for industrial and domestic use

2) Work in many product development laboratories
3) Some jobs require only a high school diploma and some technical training, while other jobs require additional training.

f) Ecological entomologists
1) Concerned with protecting and sustaining the environment and health standards
2) Regulate proper waste treatment and chemical disposal
3) Usually a bachelor's degree or higher is necessary.

5. Discuss with students how a general knowledge of insects and insect behavior can be useful in many job areas. Many times a minor emphasis in entomology is an excellent combination with another major field.

What are some careers enhanced by a working knowledge of entomology?

a) Landscaping and turf management
1) Turf management involves the care and maintenance of landscaped areas.
2) This field is very diverse depending at what level and how you want to work.
3) Entomology is an excellent minor in this area.
4) Pesticide applicator's certification may be necessary.

b) Animal and human medical care
1) Assistants and technicians in all areas need some training in insect management.
2) There are many openings at lower levels in these areas.

c) Food science
1) Food production is a very large area in which insect control is necessary at all levels.
2) An important part of food production is the preservation and the transportation of food items throughout the U.S. and the world.

d) Biological science - There are many areas in the biological and natural sciences that are enhanced by the study of insects.

F. Other activities

1. Have students list all the different products they find that contain insecticides. They can check their homes, local grocery stores, and garden supply stores for items.

2. Students can talk with people who work with the environment and get their opinion on insects and insect control.

3. Invite someone who uses entomology in his or her work to be a guest speaker. A greenhouse manager and a landscaper are two examples.

G. Conclusion

Entomologists study insects. They study their development, anatomy, physiology, life history, behavior, environment, and classification. The study of entomology is necessary in many aspects of society.

H. Competency

Discuss the significance of entomology.

I. Answers to Evaluation

1. The study of insects
2. A scientist who specializes in the study of insects
3. Harmful insects are those that cause damage to food and fiber crops and transmit diseases. Beneficial insects destroy the harmful insects, provide food and fiber products, and enhance the environment.
4. Four of the following: agricultural entomologists, entomology instructors, industrial entomologists, ecological entomologists, and medical and veterinary entomologists
5. b
6. c
7. d
8. d

J. Answers to Work Sheet 1.1

The instructor will need to evaluate this work sheet.

UNIT - ENTOMOLOGY

Name _____

Lesson 1: Introduction to Entomology

Date _____

EVALUATION

Complete the following with a short answer.

1. What is entomology?

2. What is an entomologist?

3. What are the differences between harmful and beneficial insects?

4. What are four careers in entomology?

   a.
   b.
   c.
   d.

Circle the letter that corresponds to the best answer.

5. Construction workers may use their knowledge in entomology for controlling which of the following insects?

   a. Ants
   b. Termites
   c. Roaches
   d. Flies

6. Some insects are considered harmful because they _____.

   a. Pollinate plants
   b. Provide food and fiber
   c. Destroy helpful insects
   d. Break down materials in the environment

20

7. Some insects are considered helpful because they _____.

   a. Transmit diseases
   b. Destroy food and fiber
   c. Eat wooden structures
   d. Promote drug research

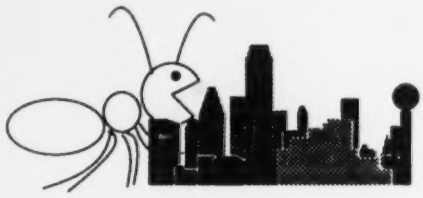
8. A knowledge of insects is useful in which of the following medical areas?

   a. Treatment of diseases
   b. Research
   c. Veterinary science
   d. All of the above

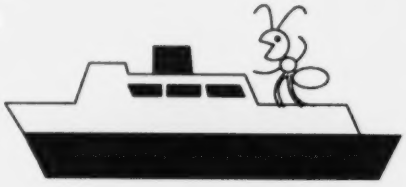
Lesson 1: Introduction to Entomology

Handout 1.1: Facts About Insects

Of all the species of living things in the world, most are insects (about 80 percent).

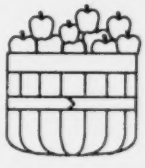


One female aphid can leave 10^{108} descendants in the course of a season.



Insects live in almost every place in the world. The only habitat that insects have not invaded to any great extent is the ocean.

Insects can cause much damage. Annual losses caused by insects in the United States have been estimated to be about $3 1/2 billion.



Insects are very beneficial to man in many ways. The value of insects pollinating fruits and vegetables alone is estimated to be about $4 1/2 billion each year in this country.

Lesson 1: Introduction to Entomology

Work Sheet 1.1: Interview

Directions: Interview a person with a career in entomology. Record his or her name, occupation and place of employment. The questions can be used as an aid when interviewing the individual.

Name:

Occupation:

Place of Employment:

How long have you worked in your present occupation?

How did you decide on this job?

What training was necessary for this job?

What professional skills do you use in this job?

What jobs have you had previously that helped prepare you for this job?

What other jobs have you considered?

What are your job/career plans for the future?

How did you get interested in entomology?

What advice would you give someone who is considering a career in entomology?

Comments:

UNIT - ENTOMOLOGY

Lesson 2: Insect Collection

Objective: The student will be able to prepare an insect collection.

Study Questions

1. **How are insects collected?**
2. **How are insects preserved?**
3. **How are insects labeled?**
4. **How are insects pinned?**
5. **How should the wings of butterflies and moths be spread?**
6. **How are insect collections arranged?**

References

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.
2. University Extension Entomology Guide Sheets (teacher reference)

   NOTE: Students could obtain additional information about their insects from an entomology guide sheet. See reference section in the introduction for a complete listing of guide sheets.
3. Transparency Masters

   a) TM 2.1: Location of Insects
   b) TM 2.2: Killing Jar
   c) TM 2.3: Mounted Insects and Labels
   d) TM 2.4: Pin Placement for Different Insects
   e) TM 2.5: Pinning Blocks
   f) TM 2.6: Spreading Board
   g) TM 2.7: Spreading an Insect
4. Demonstration Sheet

   a) DS 2.1: Butterfly Model
5. Job Sheets

   a) JS 2.1: Making a Killing Jar
   b) JS 2.2: Labeling Insects
   c) JS 2.3: Spreading the Wings of Butterflies and Moths
6. Activity Sheet

   a) AS 2.1: Making an Insect Collection

UNIT - ENTOMOLOGY

Lesson 2: Insect Collection

TEACHING PROCEDURES

A. Review

Review why insects are important to us. Emphasize how much insects affect our lives and how many people are involved in working with insects.

B. Motivation

1. Ask students where they think insects can be found: homes, lawn, garden, woods, water, and urban areas. Using TM 1.1, ask students to name insects they could find in the given areas on the picture. Examples include: tomato worms and corn bores in garden, grubs in lawn and garden, fleas on the dog, and mosquitos in water.

2. Have a pre-made or commercial insect collection displayed as an example. If this isn't possible, examples of collections can be illustrated through pictures.

3. Display visual aids such as: a piece of wood damaged by termites; grain or flour damaged by weevils; bees or flies in a jar or an ant farm; or pictures of damage or diseases caused by or carried by insects.

C. Assignment

Give instructions and procedures for making an insect collection, AS 2.1. The collection will be made using the appropriate techniques for pinning, preserving, labelling, and mounting the insects. The instructor will need to determine the number and species of insects to be collected.

D. Supervised study

E. Discussion

1. Discuss with students the different places where insects can be found. Remind students that many people are afraid of insects. Stress that most insects are not dangerous. Tell them that it is very common to be apprehensive about insects until you become more familiar with them and the ways to handle them. Have students use JS 2.1 to prepare a killing jar. Use TM 2.2 to illustrate a killing jar.

How are insects collected?

a) Prepare a killing jar.
b) Locate insects.
c) Catch insects.
    1) Bare hands
    2) A net
    3) Boxes, jars, or envelopes
d) Place insects in a killing jar.

2. Discuss the procedures for preserving insects. Samples of insect pins, preservation jars filled with alcohol, or envelopes can be used as visual aids.

How are insects preserved?

a) Pinning - This is the most common method used for most insects.
b) Liquid - Liquid is used for soft-bodied insects that shrivel when dried.
c) Envelopes - Envelopes can be used for slender and fragile insects such as dragonflies.

3. Discuss the procedures for labeling insects. Point out what information must appear on the labels and what information is extra. Use TM 2.3. Have students complete JS 2.2.

How are insects labeled?

a) Locality and ecological labels - made of stiff white paper about 1/4 by 3/4 inches
   1) All insects collected must have a locality label that contains the date and place where the insect was caught. The name of the collector may be included on the locality label.
   2) Information about the insect's environment and habitat may be on a second label called an ecological label.
   3) Labels and insects are mounted on the pin at the correct heights.
      (a) Insect - 1" mark
      (b) Locality label - 5/8" mark
      (c) Ecological label - 3/8" mark
   4) They should be positioned parallel with the body of the insect or point.
   5) Labels can be read from either the right or left so long as all labels are read in the same direction.
b) Identification labels - one square inch in size
   1) Are placed directly in an insect collection
   2) Identify groups of insects by order or identify each specimen when insects are arranged and labeled by species
   3) Are placed alongside a group or at the base of an individual insect pin
   4) Contain the order of the group of insects or the scientific name of the insect, the name of the collector, and the date of capture
c) Slide label - used for insects mounted on slides

4. Discuss the procedures for pinning insects. Pinning is a way to mount and preserve insects indefinitely. The actual pinning of an insect can be demonstrated for the students. A rubber insect can be used, and re-used, if a real one is not desired. Students might practice some pinning in class. Use TM 2.4 for pin placement and TM 2.5 for pinning blocks. TM 2.3 can be used to point out insect and label placement on pins.

How are insects pinned?

a) Pinning should be done as soon as insects are collected.
b) The insect is held between the thumb and forefinger of one hand while the pin is inserted with the other hand.
c) Insects are pinned in particular places depending on the type of insect.
d) Insects and labels are mounted on the pin at certain heights: 1, 5/8, and 3/8 inches. A pinning block can be used to make mounting easier.
e) Small insects are mounted on a point.
   1) Points are small, triangular pieces of cardboard mounted on the pin.
   2) The insect is glued to the extended point of the triangle.
   3) Insects are attached with glue or household cement.

5. Discuss the procedures for spreading the wings of butterflies and moths. To illustrate the spreading technique, use the butterfly provided in DS 2.1 to make a model out of stiff paper or cardboard. The paper wings can be spread into the proper positions as the students watch. Students can practice with the model later. The use of a spreading board can be demonstrated if one is available. Use TMs 2.6 and 2.7. Have students complete JS 2.3.

How should the wings of butterflies and moths be spread?

The steps for spreading the wings of a butterfly or moth on a spreading board are given below. If a spreading board is not available, turn the insect upside-down to spread the wings on a flat surface.

1) Hold the specimen by grasping it by the thorax, the middle section of the insect. Holding it right side up, insert a pin through the middle of the thorax. Move it to the 1-inch position on the pin. The pinned specimen is then lowered onto the spreading board. The pin should go into, and maybe even through, the bottom of the groove. Push the pin through the board until the underside of the wings is even with the top piece of the spreading board. Pin narrow strips of paper over the wings on each side.
2) Remove the pin on one side at the lower end of the strip of paper. Raise the front wing until the rear edge is at a right angle to the body. Forceps, a pin, or some other tool may be helpful in doing this. Be careful not to tear or puncture the wing. When the wing is in place, insert a pin through the strip of paper just in front of the tip of the wing. Pin the lower edge of the paper strip back into place.
3) Repeat this procedure with the other front wing.
4) Using forceps, a pin, or some other tool to raise the hind wing on one side until the space between the two wings is reduced. The front and hind wings of these insects will overlap at the base with the front edge of the hind wing under the rear edge of the front wing. Move the pin in the lower part of paper strip until it is just below the tip of the hind wing.
5) Repeat this procedure with the hind wing on the other side.
6) Now, position the antennae so that they appear balanced. Put pins alongside the antennae to hold them in place.
7) Fasten the legs close to the body at right angles to the body. This is done by placing a strip of paper across the entire body.
8) The insect is left in position until it is dry. This will depend on the size of the insect, the temperature, and the humidity.

6. Discuss the procedures for arranging insect collections. An insect collection that is already made can be displayed for the students, if one is available.

How are insect collections arranged?

There is no exact way to organize an insect collection. The way the insects are arranged will depend on the size of the collection, the types of insects collected, and the preference of the individual. However it is done, the collection should be neat and orderly and the insects easily seen. Insect collections are arranged in display boxes for study and storage. There are several kinds of display containers.

a) Mounting box
   1) The most common type used
   2) Made of wood or heavy cardboard
   3) Measure about 9 x 12 x 3 inches and have a tight-fitting lid
   4) The bottom is lined with a soft and sturdy material (usually sheet cork, balsa wood, Styrofoam, or corrugated cardboard).

b) Riker mount
   1) A box with a single glass top
   2) Filled with cotton
   3) Insects are seen easily.
   4) Mounts can be handled without damaging the specimens.
   5) Only one side of the insect can be seen.
   6) Some insects tend to fade after extended exposure to the light.

c) Glass mounts
   1) A box with glass sides on the top and the bottom
   2) Similar in material and size to the Riker mount
   3) Contains no cotton
   4) Both sides of the insect can be seen.
   5) Each glass mount contains only a few insects.

d) Plastic mounts
   1) Consist of two sheets of thick plastic
   2) The insect is mounted between them.
   3) The edges are sealed with acetone or tape.
   4) Another method is to embed insects in a block of plastic.
   5) The process is very involved but the result is attractive and very durable.

e) Slide mounts
   1) Slide mounts allow insects or parts of insects to be studied in detail.
   2) Dark-colored samples are treated before mounting in order to be seen better.
   3) Various chemicals are used on the samples before mounting and viewing.

NOTE: Insect collections may be attacked and damaged by beetles and other pests. Special repellents, which are placed in a small pillbox or on a piece of cloth, should be put in the corner of the display box or underneath the cotton in Riker mounts.

F. Other activities

1. Have a contest featuring the best insects collected in each of several categories (possibly by class vote). Some suggestions are the biggest, the smallest, the most colorful, the ugliest, the prettiest, the most rare, and the best mounted. These can be exhibited with a description label as a display for the class or school. Bonus points may be offered.

2. A covered terrarium can be set up at the beginning of the unit. It could contain a piece of wood and some termites, an ant farm, or a bee colony. Observe the insects throughout the Entomology course.

G. Conclusion

Insects can be found almost anywhere. Species are best identified by the use of keys or guides. Preparing an insect collection is a good way to study insects and learn about their environment.

H. Competency

Prepare an insect collection

I. Answers to Evaluation

1.	b	4.	c	7.	d
2.	b	5.	c	8.	c
3.	d	6.	a		

9. A "point" is a small triangular piece of paper used for mounting small insects.

UNIT - ENTOMOLOGY Name _____

Lesson 2: Insect Collection Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. When are insects pinned?

   a. After drying
   b. Immediately after they are killed
   c. Before they are killed
   d. After they are mounted

2. Which of the following would not be used for preserving insects?

   a. Envelopes
   b. Spreading board
   c. Insect pins
   d. Liquids

3. Which method should be used to kill insects for a collection?

   a. Inserting a pin through the thorax
   b. Using your bare hands
   c. Spraying them with herbicide
   d. Using a killing jar

4. Where is the pin inserted for beetles and grasshoppers?

   a. The scutellum
   b. The rear edge of the head
   c. The front part of the right wing
   d. The abdomen

5. What is the correct height for the first label on a pin?

   a. 1/2 inch
   b. 3/5 inch
   c. 5/8 inch
   d. 1 inch

6. When the wings of a butterfly are properly spread, which of the following must be true?

   a. The front and hind wings overlap.
   b. A spreading board must be used.
   c. The front and hind wings do not overlap.
   d. The insect will be in an upside-down position.

7. On the first label, which of the following must be included?

   a. The date the insect was pinned
   b. The name of the collector
   c. How the insect was preserved
   d. The place the insect was found

8. Which of the following is not contained in an insect collection?

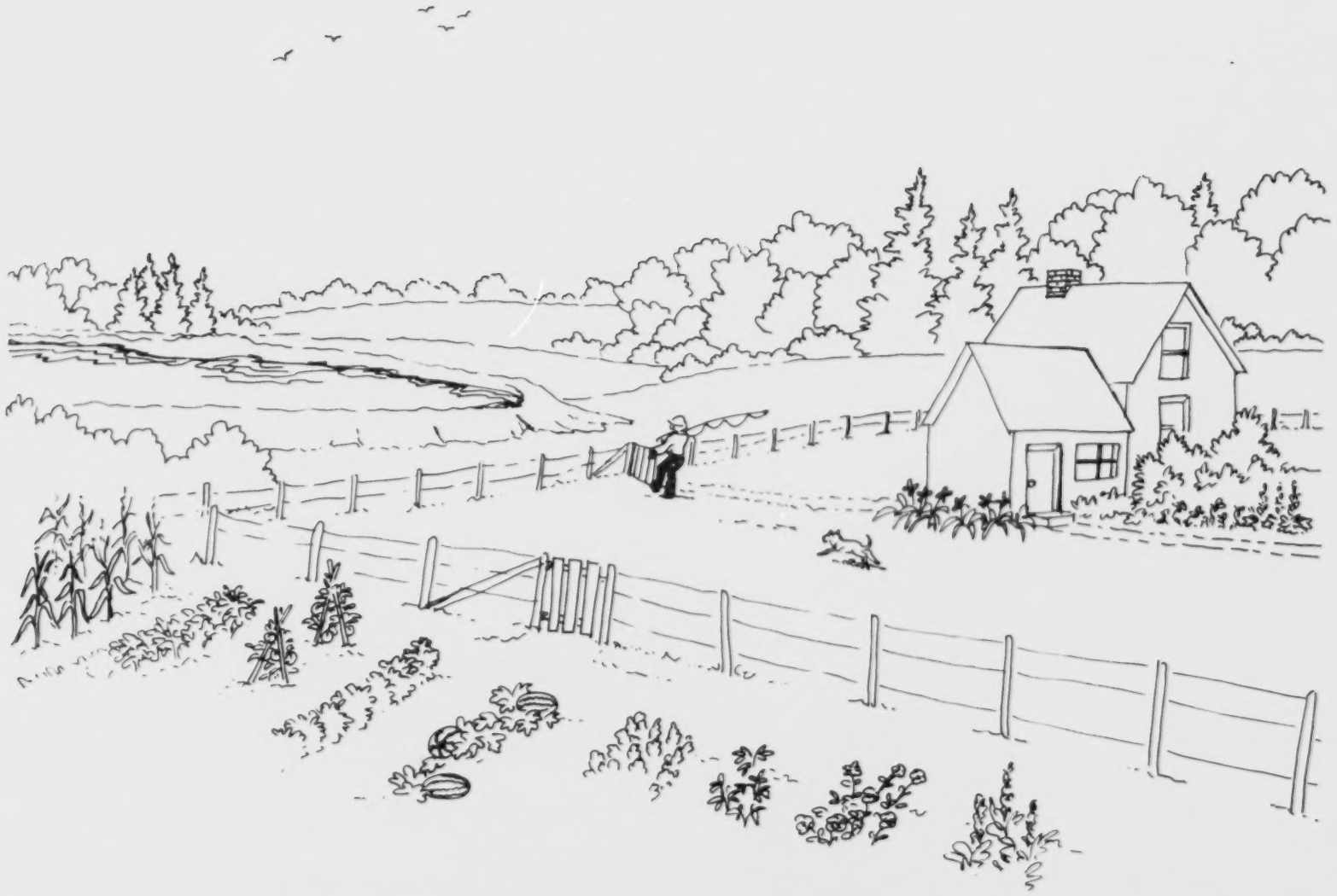
   a. Preserved insect specimens
   b. Identification labels
   c. Killing agent
   d. Insect pins

Answer the following short answer question.

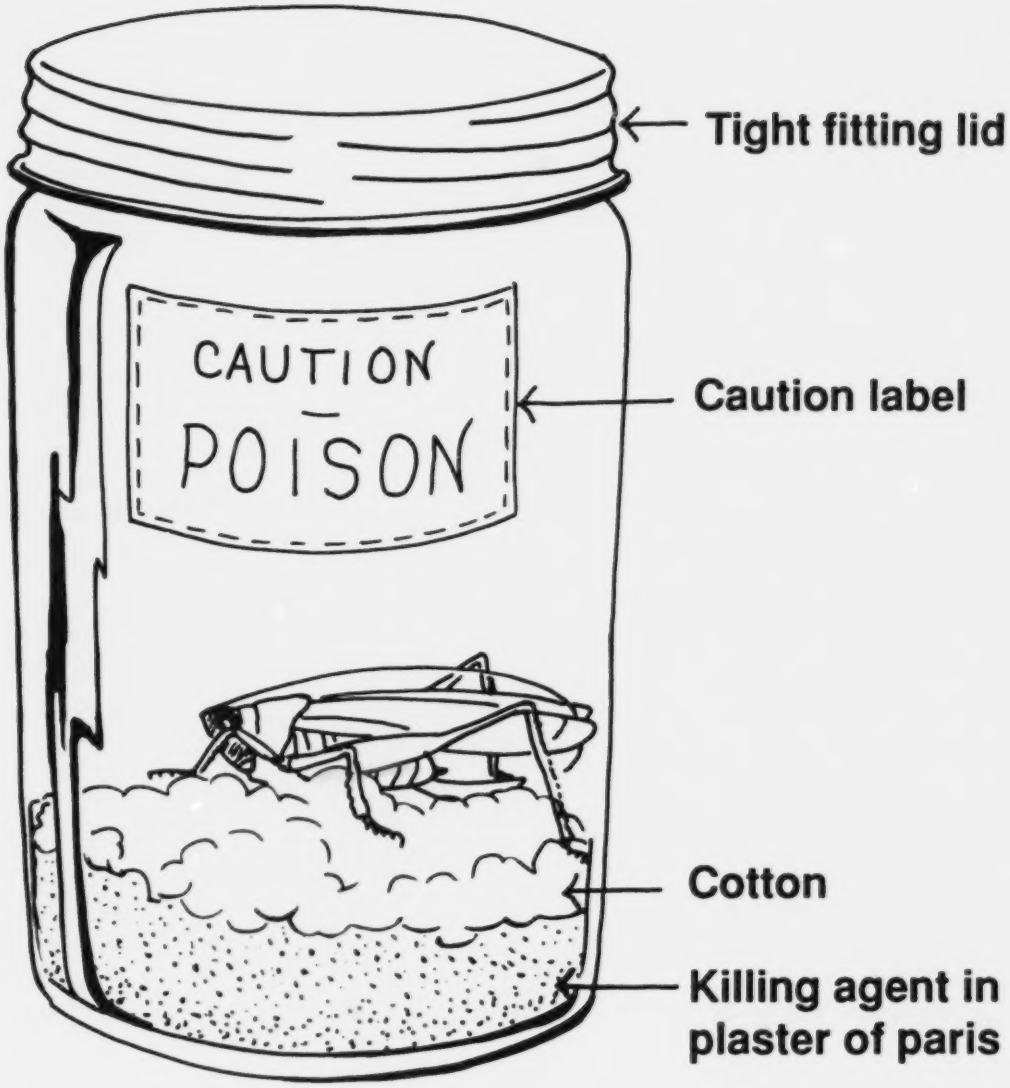
9. What is a "point"?

30

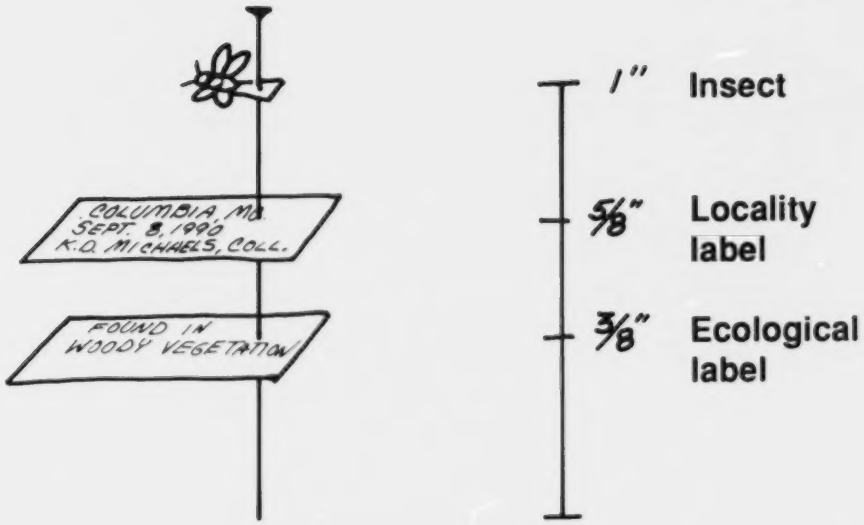
Location of Insects



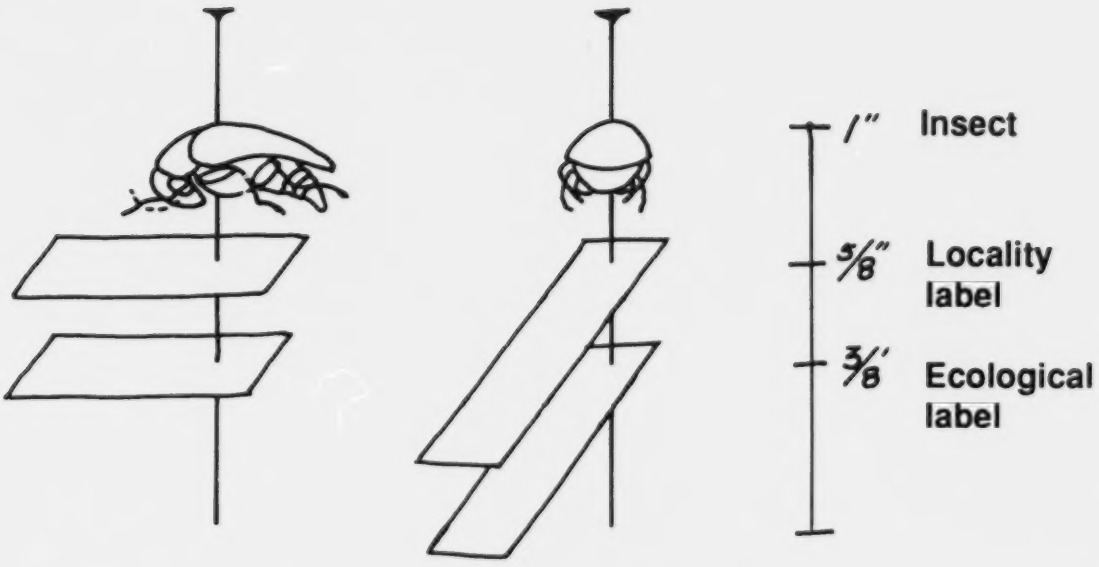
Killing Jar


Tight fitting lid
CAUTION
POISON
Caution label
Cotton
Killing agent in plaster of paris

Mounted Insects and Labels

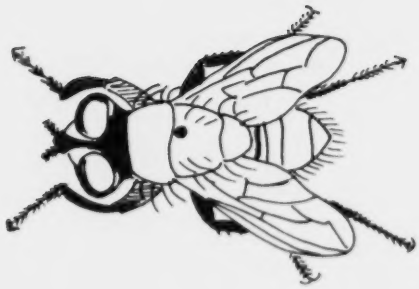


A small insect mounted on a point

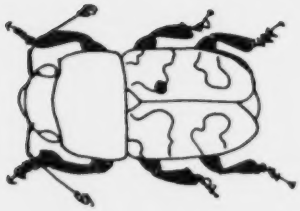


A properly mounted beetle

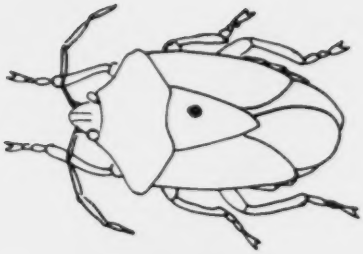
Pin Placement for Different Insects



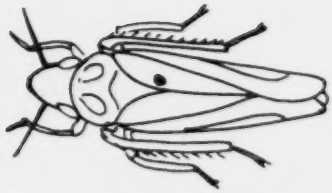
Flies



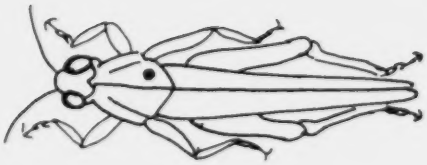
Beetles



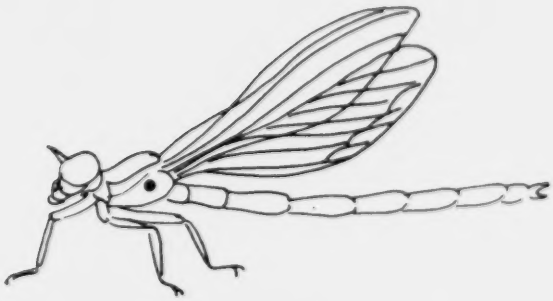
Bugs



Leafhoppers



Grasshoppers

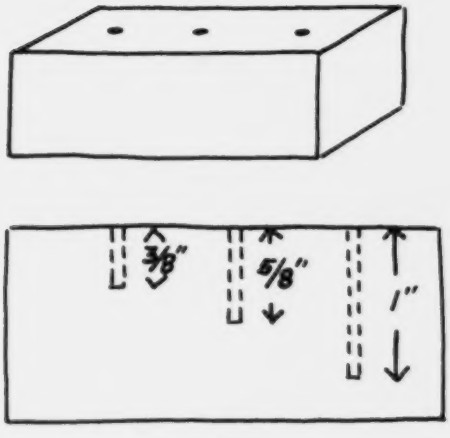


Dragonflies & Damselflies

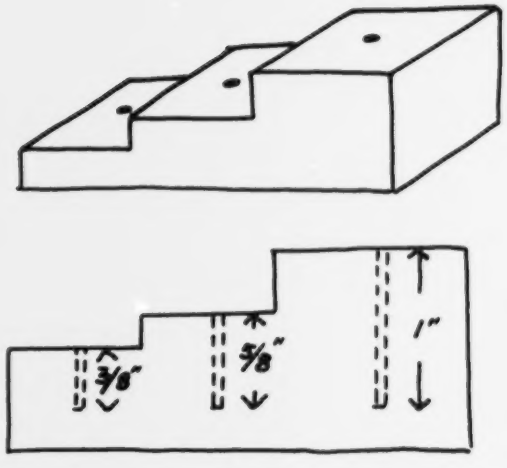
Black dot indicates pin placement.

Pinning Blocks

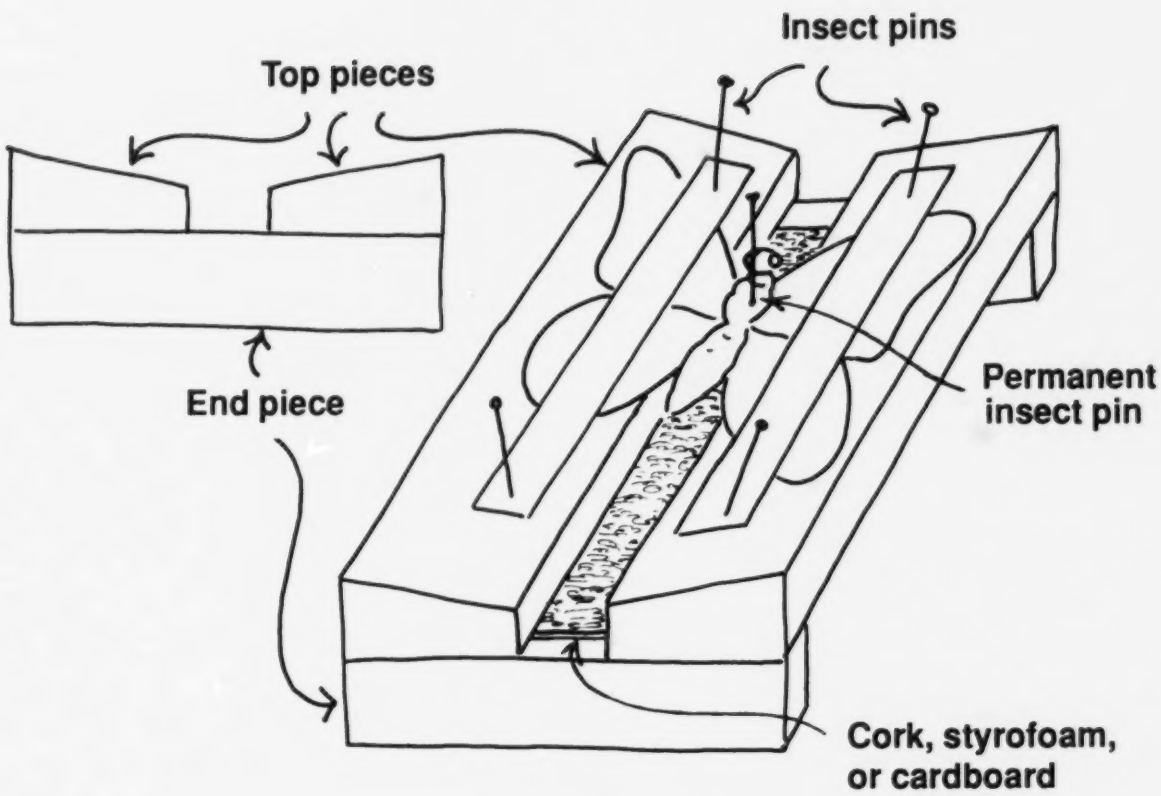
Rectangular Block



Stair-step Block

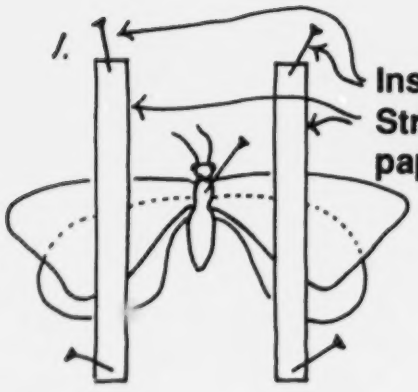


Spreading Board



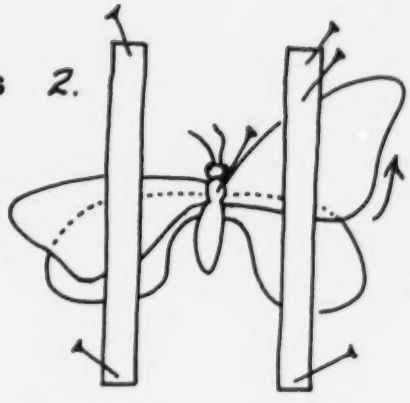
Spreading Board

Spreading an Insect

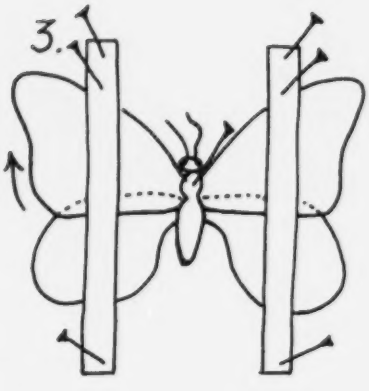


Insect pins
Strips of paper

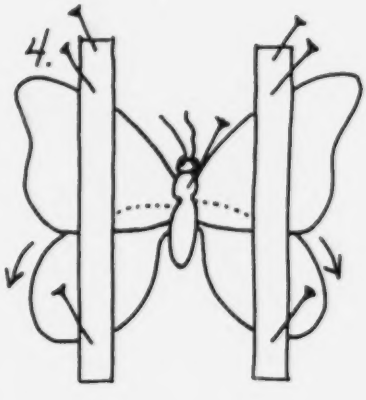
Position insect on spreading board



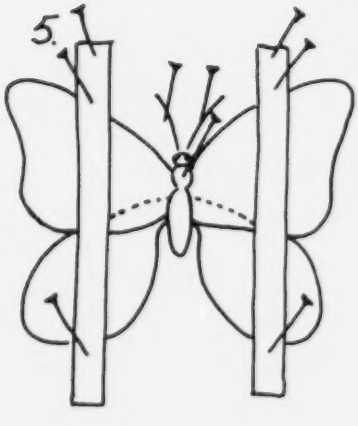
Position front wing



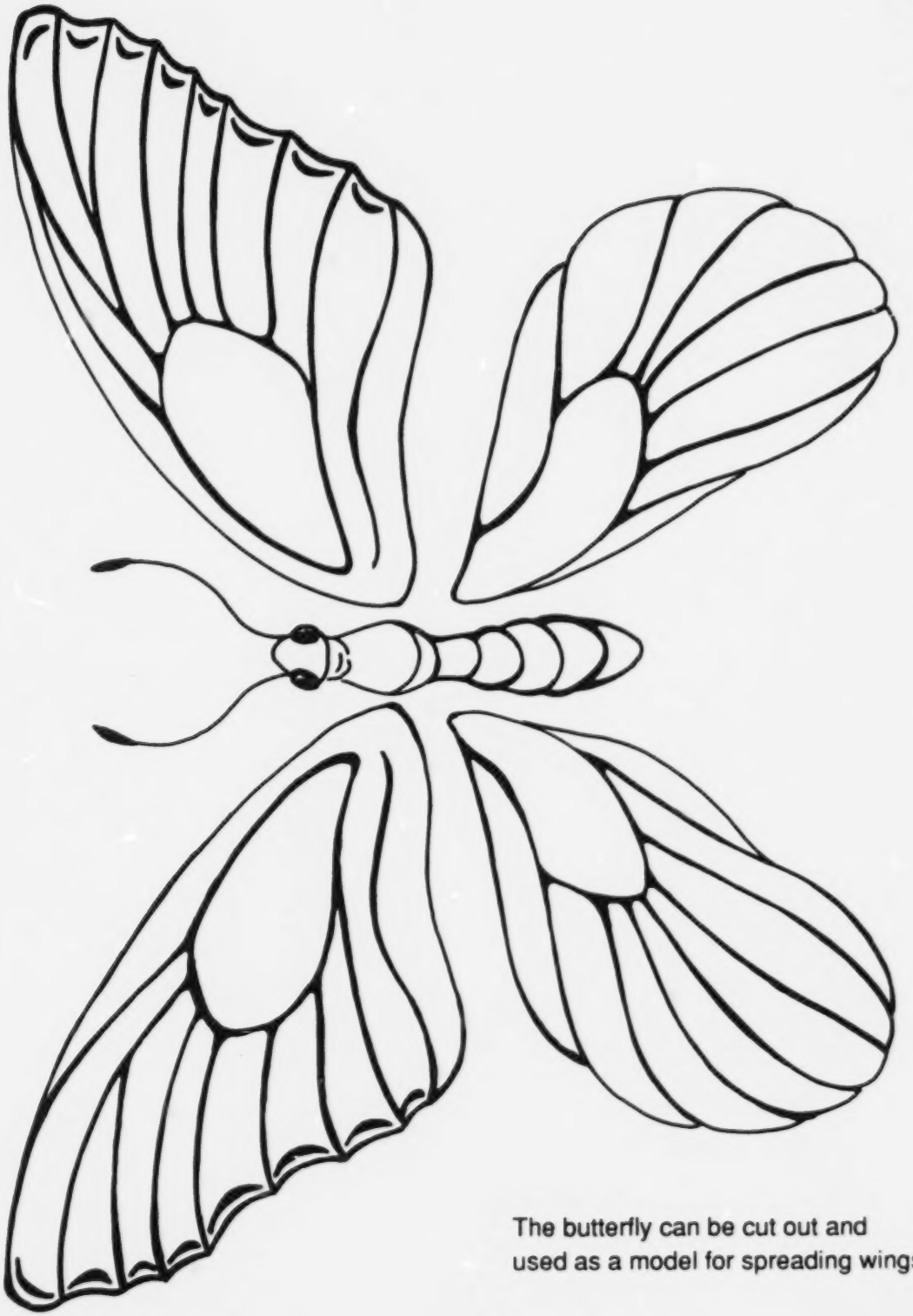
Position other front wing



Position hind wings



Position antennae



The butterfly can be cut out and used as a model for spreading wings.

Lesson 2: Insect Collection

Job Sheet 2.1: Making a Killing Jar

Objective: The student will be able to make a killing jar.

Materials and supplies needed:

1. Wide-mouth jar, 6 to 16 oz. size with a screw-on lid
2. Bowl or container for mixing
3. Plaster of paris
4. Water
5. Ethyl acetate (killing agent)
6. Cotton
7. Tape, masking or electrical
8. Labels

Procedure:

1. In the bowl or container, add water to the plaster of paris until a thick mixture is made.
2. Pour the mixture into the jar to a height of about 1 inch (20-30 millimeters).
3. Allow the mixture to air dry at room temperature (this requires several days) or under low heat (light bulb or lowest oven temperature) until completely dry.
4. Pour ethyl acetate onto the plaster of paris to cover it.
   CAUTION: Be careful not to breathe the fumes.
5. Cover the jar to prevent the fumes from escaping.
6. Let it stand a few minutes so that the plaster of paris can fully absorb the ethyl acetate.
7. Pour off any excess ethyl acetate and replace the lid. There should not be any standing liquid.
8. Place enough cotton to cover the plaster of paris. The insect should not come into direct contact with the plaster of paris.
9. Place tape on the bottom and lower sides of the jar to reduced the chance of breakage.
10. Label the jar "poison."
11. Reapply ethyl acetate to the plaster of paris after several hours of collecting insects as needed. Always leave the lid on unless the collector is actually placing an insect in or removing one from the jar.

Lesson 2: Insect Collection

Job Sheet 2.2: Labeling Insects

Objective: The student will be able to label insects properly by species.

Materials and supplies needed:

1. Stiff white paper
2. Scissors
3. Pen or marker
4. Insect pins
5. Insects (number to be determined by instructor)

Procedure:

1. Cut small pieces of paper, about 1/4 by 3/4 inches or smaller, out of fairly stiff white paper.

2. Prepare the locality label first. Write the date when the insect was found and the place where the insect was found. The name of the collector can also be place on this label. All information should be written accurately and clearly.

3. On a second label, write any additional information or observations on the insect's environment. This label is called the ecological label.

4. Mount the labels on the pin at the proper height(s) and parallel with the insect (or point). See Figure 2.1.

   a) Insect - 1" mark
   b) Locality label - 5/8" mark
   c) Ecological label - 3/8" mark

5. After the specimens are arranged in groups according to order, prepare identification labels.

   a) Cut out pieces of paper about one inch square. You will need one label to identify each specimen.

   b) Write the scientific name of the insect, the name of the person identifying it, and the month and year when the identification was made on the label.

   c) Place these identification labels at the base of each specimen.

   Note: If the identification labels are used to identify the orders, place a label by each order. This label should contain the name of the order and the collector.

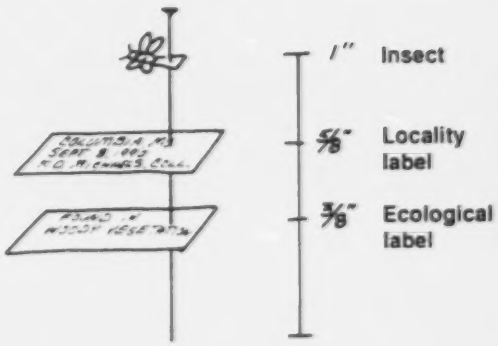


Figure 2.1

Lesson 2: Insect Collection

Job Sheet 2.3 - Spreading the Wings of Butterflies and Moths

Objective: The student will be able to spread the wings of butterflies and moths.

Materials and supplies needed:

1. Winged insect specimen
2. Spreading board
3. Insect pins
4. Narrow strips of paper
5. Forceps, tweezers, or similar tool

Procedure:

NOTE: Always handle the specimen with care so that the parts are not damaged. The following procedure is followed when a spreading board is used.

1. Gently grasp the insect specimen by the thorax, the middle section of the insect, and hold it right side up.
2. Insert an insect pin through the center of the thorax.
3. Move the insect to the 1-inch position on the pin.
4. Lower the pinned specimen onto the spreading board. The pin should go into, and maybe even through, the bottom of the groove.
5. Push the pin through the board until the underside of the wings is even with the top piece of the spreading board.
6. Pin narrow strips of paper over the wings on each side to hold them in place. See Figure 3.1.
7. Remove the pin on one side at the lower end of the strip of paper.
8. Raise the front wing until the rear edge is at a right angle to the body. Forceps, a pin, or some other tool may be helpful in doing this. Be careful not to tear or puncture the wing. See Figure 3.2.
9. When the wing is in place, insert a pin through the strip of paper just in front of the tip of the wing.
10. Pin the lower edge of the paper strip back into place.

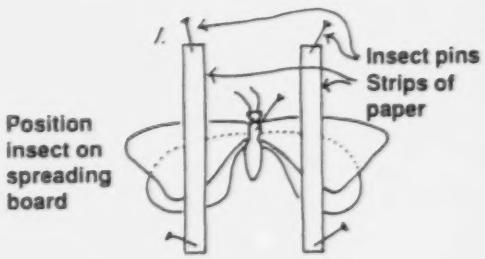


Figure 3.1

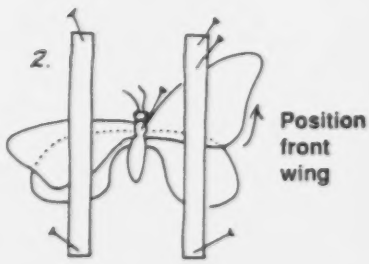


Figure 3.2

11. Repeat this procedure with the other front wing. See Figure 3.3.

12. Using forceps, a pin, or some other tool, raise the hind wing on one side until the space between the front and hind wings is reduced. The front wing will overlap the hind wing. See Figure 3.4.

13. Move the pin in the lower part of paper strip until it is just below the tip of the hind wing.

14. Repeat this procedure with the hind wing on the other side.

15. Position the antennae so that they appear balanced.

16. Put pins alongside the antennae to hold them in place. See Figure 3.5.

17. Fasten the legs close to the body at right angles to the body by placing a strip of paper across the entire body.

18. Prepare 1 or 2 labels. (Refer to JS 2.2.)

19. Allow the insect to dry in place. This may take from a few hours to a few days.

20. When the insect is dry, carefully remove the strips of paper and mount the insect with labels.

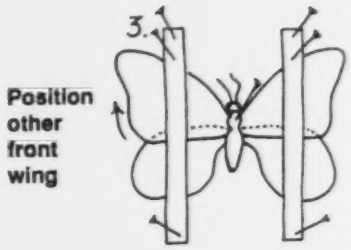


Figure 3.3

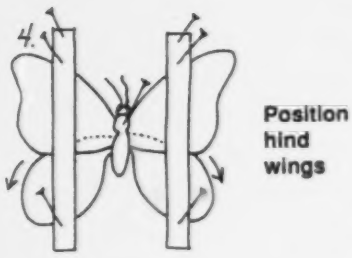


Figure 3.4

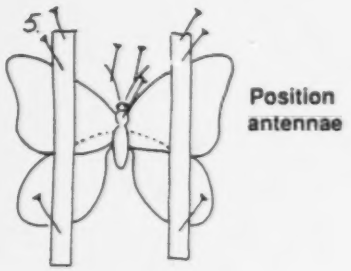


Figure 3.5

Lesson 2: Insect Collection

Activity Sheet 2.1: Making an Insect Collection

Objective: The student will be able to make an insect collection.

Materials and supplies needed:

1. Killing jar
2. Student reference
3. Collection box
4. Insect pins
5. Labels
6. Insects - number to be determined by the instructor

Procedure:

1. Make a killing jar. (Refer to JS 2.1.)
2. Locate and catch the insects. (Refer to student reference.)
3. Place the insect in the killing jar as soon as possible.
4. Spread the insect's wings if necessary. (Refer to JS 2.3.)
5. Pin the insects in the appropriate way and place them so that they rest one inch up on the pin. (Refer to student reference.)
6. Prepare the labels. (Refer to JS 2.2.)
7. Mount the locality label (first label) at the 5/8 inch mark on the insect pin.
8. Mount the ecological label (second label), if there is one, at the 3/8 inch on the insect pin.
9. Arrange the mounted insects in a collection box by orders.
10. Add identification labels.

UNIT - ENTOMOLOGY

Lesson 3: Insect Identification

Objective: The student will be able to describe the procedure for classifying insects to order.

Study Questions

1. **What are the distinguishing characteristics of an insect?**
2. **What are the three main sections of an insect?**
3. **What are the different life stages of insects?**
4. **How are insects classified?**
5. **What are the distinguishing characteristics of the insect orders?**

References

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.
2. Transparency Masters
   a) TM 3.1: Three Main Sections of an Insect
   b) TM 3.2: Types of Antennae
   c) TM 3.3: Types of Mouth Parts
   d) TM 3.4: Types of Insect Legs
   e) TM 3.5: Examples of Wings
   f) TM 3.6: Stages of Development
   g) TM 3.7: Incomplete Metamorphosis
   h) TM 3.8: Complete Metamorphosis
   i) TM 3.9: Insect Classification
3. Handout
   a) HO 3.1: Systematic Method to Identify Insect Orders
4. Work Sheets
   a) WS 3.1: Insect Fact Sheet
   b) WS 3.2: Insect Orders

UNIT - ENTOMOLOGY

Lesson 3: Insect Identification

TEACHING PROCEDURES

A. Review

Review the importance of an insect collection and where insects are found. This lesson introduces procedures for identifying the insects being collected and how to organize them for the display.

B. Motivation

Students will begin completing WS 3.1, Insect Fact Sheet. Explain the purpose of the project to students. Each student is assigned an insect and given a blank Insect Fact Sheet to complete. Emphasize that the fact sheet needs to be kept up on a regular basis. The information compiled throughout the Entomology unit will be used to make their Insect Pest Management Plan in Lesson 7.

C. Assignment

Students should be able to complete questions 1-10 on their Insect Fact Sheet (WS 3.1) after this lesson.

D. Supervised study

E. Discussion

1. The students now know where to look for insects, how to collect them, and how to prepare specimens for a collection. The next step is to learn the details of insect bodies, the distinguishing features of each order, and how insects are divided into groups. Discuss the particular features that identify insects and separate them from other animals.

   What are the distinguishing characteristics of an insect?

   An insect is defined as a small animal without a backbone that has the following external characteristics as an adult:
   a) A hardened external skeleton
   b) Three distinct body regions: head, thorax, and abdomen
   c) One pair of segmented antennae
   d) Three pairs of segmented legs on the thorax segment
   e) One pair of compound eyes; some insects have no eyes
   f) One or two pairs of wings; some adults are wingless

2. The best way to study and identify insects is by looking at the three main sections of an insect. Use TMs 3.1 - 3.5.

   What are the three main sections of an insect?

   a) Head - the hardened region at the front of the body including the eyes, antennae, and mouth parts
      1) There are two types of eyes.
         (a) Simple eyes - small, located on the top of the head of the adult

(b) Compound eyes - large, located on the head of the adult; made up of a few to several thousand individual eye units, which generally see only light and dark areas

2) Insects have one pair of antennae.
   (a) Long, jointed feelers
   (b) Grow from the insect's head
   (c) Flexible
   (d) Come in a variety of shapes
   (e) Function as sensors to detect the odor, sound, taste, and touch of the environment
3) There are different types of mouth parts.
   (a) Chewing
   (b) Piercing-sucking
   (c) A combination or modification of the other two

b) Thorax - middle section of an insect's body
   1) Contains the nerve centers and muscles.
   2) The wings and legs are attached to the thorax. These come in numerous shapes and patterns depending on the species and function.

c) Abdomen - the section located at the rear of the insect's body
   1) Visible or hidden under the wings
   2) Contains the insect's internal organs (stomach and intestines)
   3) A place to store and carry food back to the nest
   4) Sexual organs located here
   5) Contains glands that secrete fluids for making trails or driving enemies away
   6) May have a needle-like projection for piercing or stinging

3. The development of insects refers to their growth in size and changes in form. There are three stages of development for every insect. Use TMs 3.6, 3.7, and 3.8.

What are the different life stages of insects?

a) The embryo stage
   1) Insects begin life as an embryo within an egg.
   2) The embryo lives on a nutritious yolk.
   3) Hatching may take days, weeks, or months.

b) The immature stage
   1) After hatching, the insect is called an immature.
   2) The life of an immature is divided into growth stages called instars.
   3) Insects progress from one instar to the next by periodically making a new outer layer and shedding the old one. The shedding process is called molting.
   4) The process continues - instar growth stage, molting, instar growth stage, molting, etc. - until the insect becomes an adult. This is called metamorphosis.
   5) There are two systems of development, or metamorphosis.
      (a) Incomplete metamorphosis
         (1) The immature looks like a small adult.
         (2) The immature is called a nymph.
         (3) Nymphs eat the same foods as the adults.
         (4) Changes in development are mainly an increase in size, wing development, and sexual organs.
         (5) Examples include grasshoppers, thrips, stink bugs, leafhoppers, and aphids.
      (b) Complete metamorphosis
         (1) The immature does <u>not</u> look like the adult.
         (2) Immatures are called larvae.

(3) Larvae do not eat the same foods as the adults.
(4) There are numerous dramatic changes in development, both on the inside and the outside of the body.
(5) They contain one additional growth stage, the pupa.
(6) Some insects surround themselves with a cocoon.
(7) The insect develops greatly while a pupa.
(8) The insect breaks out of the pupa (and cocoon) when the adult body is fully formed.
(9) Examples include lady beetles, weevils, flies, and moths.

c) The adult stage
   1) The insect emerges from the pupa with crumpled wings and a soft body.
   2) The adult body dries, hardens, and develops color within minutes to hours.
   3) Depending on the species, adults may live from 1 hour to 20 years. In general though, adults only live a few weeks.

4. A system for classifying insects is important to identify each type of insect properly. Use TM 3.9. Handout 3.1 uses a flow chart system to help in identifying insect orders.

How are insects classified?

a) All animals, including insects, are classified by characteristics that are similar. The animal kingdom is the most general category. It is divided into groups until the insects that are most alike are classified together.
b) A scientific name is given to each insect.
   1) Genus - first part of name, written capitalized
   2) Species - second part of name, written lower case
c) Field guides or insect keys are references that usually include the following information:
   1) Description of the insect
   2) Distinguishing features of the order
   3) How different insects are related to one another
   4) The lifestyle and environment of the insect

5. Discuss the differences in the insect orders and point out what features are used to distinguish each. Since there is not enough time to go through all the orders in detail, give an overview of the orders.

What are the distinguishing characteristics of the insect orders?

NOTE: A brief summary of the distinguishing characteristics of each of the orders is given in the Student Reference. The information is presented in the following order:

a) The scientific name of the order
b) What the name means
c) The common name, if there is one
d) The number of species
e) The type of metamorphosis
f) The type of mouth parts
g) A description of the body: wings, eyes, other distinguishing traits or activities

Insect wing structure and shape are important in insect identification. The following questions can be used to help students become familiar with the orders.

a) Which orders have piercing-sucking mouth parts?
b) Which orders have complete metamorphosis?
c) Which order has a name meaning "long wing"?
d) To which order do roaches belong?

e) Which order in commonly called "beetles"?
f) Which orders have small eyes as a distinguishing feature?
g) Which orders are parasitic?
h) Which order has thick, horny wing covers?

Have students identify the order in which their individual insect belongs and what its characteristics are. Information can be written on their Insect Fact Sheet (WS 3.1).

F. Other activity

Divide the students into small groups. Have each group look up the order and characteristics of any selected insects or insects collected so far. Have a contest where the group correctly identifying a selected insect first wins.

G. Conclusion

Insect characteristics commonly used to identify and classify insects are the wings, body shape, mouth parts, and type of metamorphosis. Insect identification can be done in a systematic way using guides or keys.

H. Competency

Describe the procedure for classifying insects to order.

I. Answers to Evaluation

1. c
2. d
3. d
4. a
5. c
6. a
7. c
8. b
9. b
10. a

J. Answers to Work Sheets

a) WS 3.1
The instructor will need to determine if answers are appropriate.

b) WS 3.2
Answers are on the following page.

Lesson 3: Insect Identification

Work Sheet 3.2: Insect Orders

Complete the following chart on the insect orders.

Insect Order	Meaning of Name	Common Name	Type of Metamorphosis	Type of Mouth Part
Phasmida	phantom	walking stick or leaf	incomplete	chewing
Isoptera	equal wings	termites	incomplete	chewing
Embioptera	lively wings	web spinners	incomplete	chewing
Thysanura	tassel tail	bristletails, silverfish	none	chewing
Collembola	glue peg	springtails	none	chewing
Coleoptera	sheath wings	beetles	complete	chewing or chewing-lapping
Zoraptera	pure, wingless	Zorapterans	incomplete	chewing
Orthoptera	straight wings	grasshoppers, crickets, locusts	incomplete	chewing
Lepidoptera	scale wings	butterflies, moths	complete	piercing-sucking
Mecoptera	long wings	scorpion flies	complete	chewing
Neuroptera	nerve wings	lacewings, dobson flies, ant lions, alderflies	complete	piercing-sucking
Diplura	double tail	campodeids, japygids	none	chewing
Hymenoptera	membrane wings	ants, bees, wasps	complete	chewing or chewing-sucking
Anoplura	unarmed tail	sucking lice	incomplete	piercing-sucking
Siphonaptera	tube, wingless	fleas	complete	reduced chewing
Dermaptera	skin wings	earwigs	incomplete	chewing
Odonata	toothed	dragonflies, damselflies	incomplete	chewing
Protura	first tail	Proturans	none	piercing-sucking or chewing
Grylloblattodea	cricket cockroach	rock crawlers, icebugs	incomplete	chewing

UNIT - ENTOMOLOGY

Name _____

Lesson 3: Insect Identification

Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What body features do all insects have in common?

   a. Three body regions, six legs, wings
   b. Hardened body regions, antennae, compound eyes
   c. Three body regions, antennae, six legs
   d. Hardened skeleton, antennae, wings

2. What are the three main parts of an insect?

   a. Head, thorax, six legs
   b. Head, antennae, and abdomen
   c. Head, six legs, abdomen
   d. Head, thorax, abdomen

3. Where are the legs of an insect attached?

   a. The head and thorax
   b. The thorax and abdomen
   c. The abdomen
   d. The thorax

4. What are two types of insect mouth parts?

   a. Chewing and sucking
   b. Sucking and slurping
   c. Grinding and tearing
   d. Tearing and siphon

5. Which two phases is an insect between when it makes a cocoon?

   a. Nymph and adult
   b. Pupa and adult
   c. Larva and pupa
   d. Nymph and pupa

6. In which stage are insects identified by instars and molting?

   a. Immatures
   b. Embryos
   c. Adults
   d. Molters

7. What is molting?

   a. The stage when an insect begins its life as an adult
   b. The stage when an insect emerges from the egg to become an embryo
   c. The shedding of the hard, outer layer of skin between instars
   d. The shedding of the soft, inner layer of skin between instars

8. How many insect orders are presently identified?

   a. 32
   b. 29
   c. 26
   d. 24

9. What are the two parts of the scientific name of an insect?

   a. Order and family name
   b. Genus and species name
   c. First and last name
   d. Incomplete and complete name

10. Why is an insect field guide used for insect identification?

   a. Nobody can memorize all the information on insect classification.
   b. You may not have a good insect collection handy.
   c. Insect classification varies among entomologists.
   d. They usually have simple descriptions and no pictures of an insect.

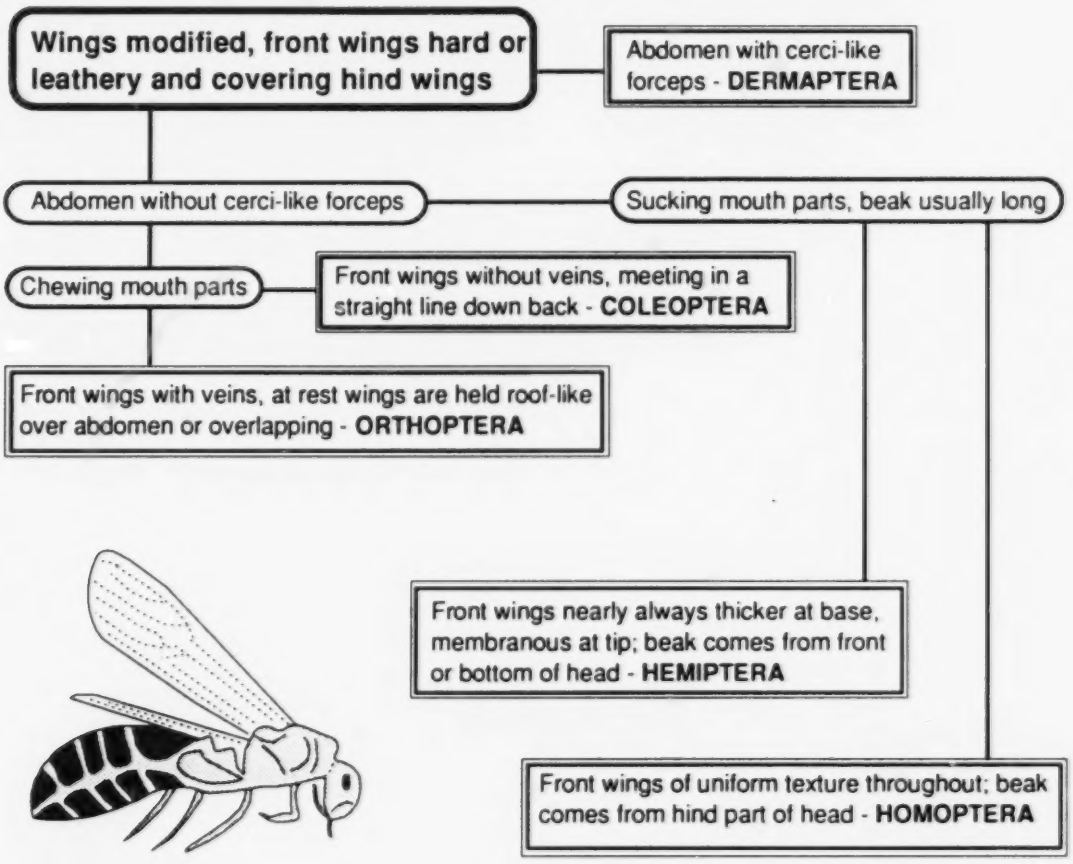
Lesson 3: Insect Identification

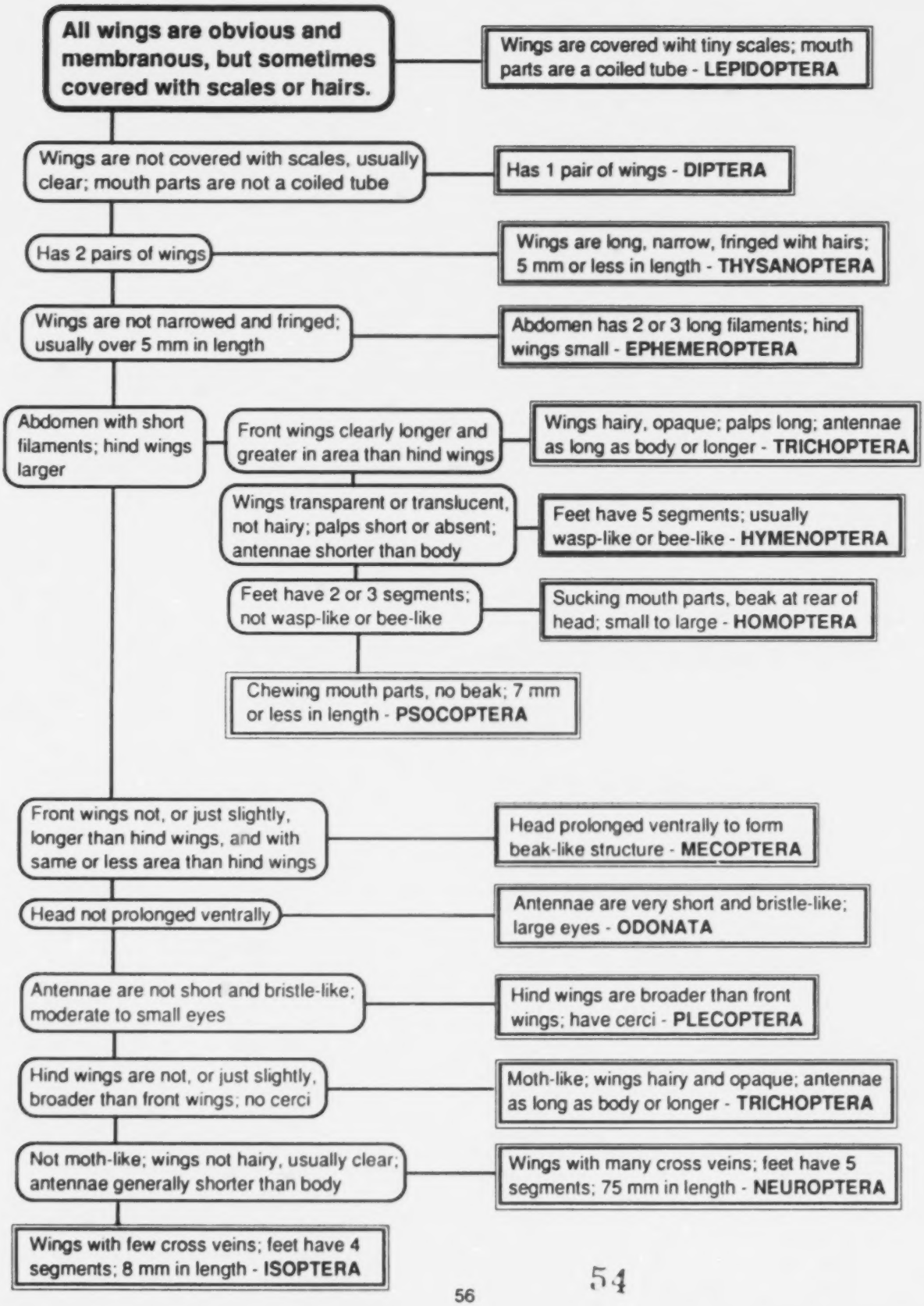
Handout 3.1: Systematic Method to Identify Insect Orders

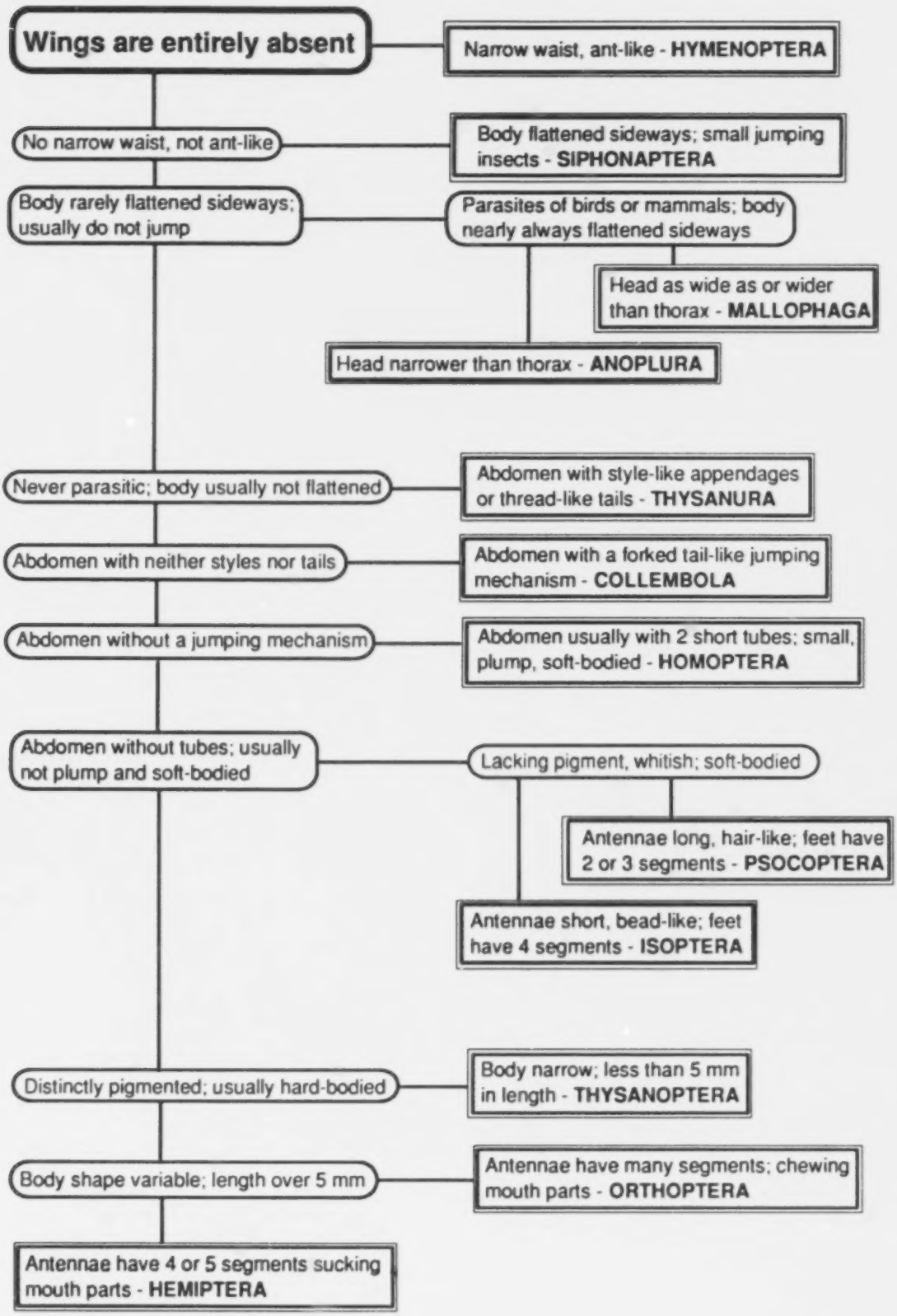
Keys are often used in identifying insects. Using a flow chart system helps to quickly identify insects and place them in the correct orders. To begin, first identify what type of wings the insect has. There are three main classes:

1. Wings are modified, front wings are hard and leathery and cover hind wings.
2. All wings are obvious and membranous, but sometimes they are covered with scales or hairs.
3. Wings are entirely absent.

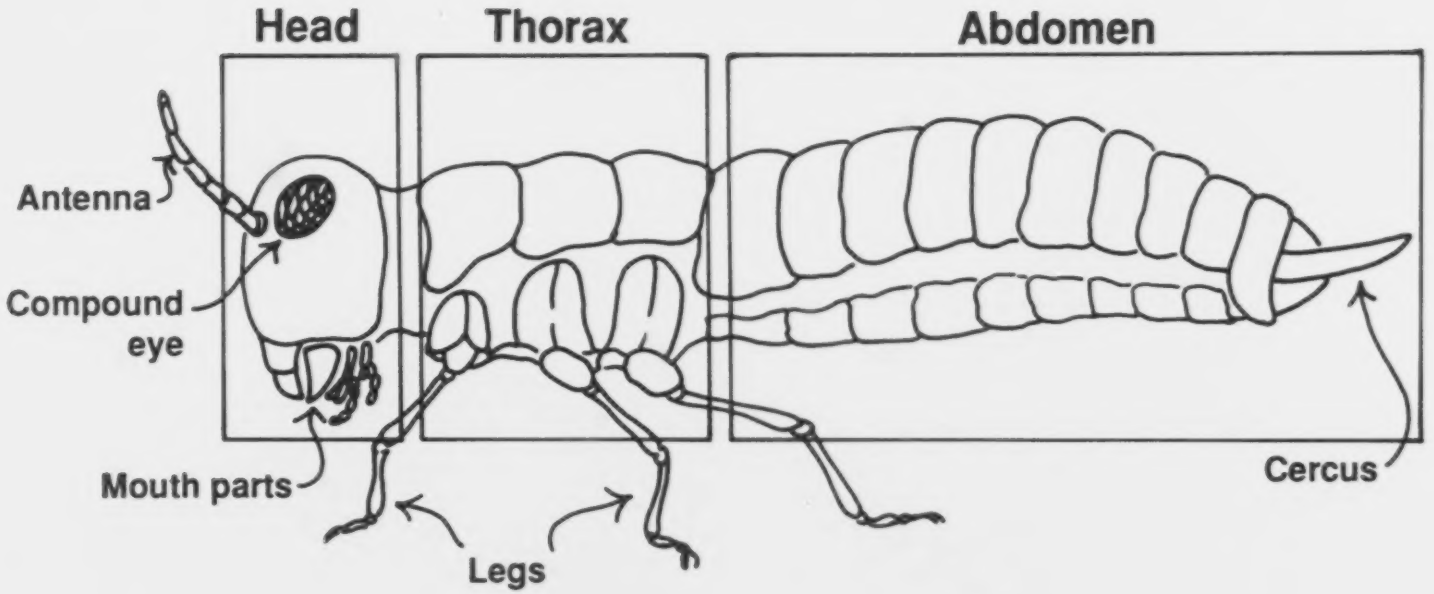
Then, proceed through the flow chart identifying characteristics until the correct order is found. A rectangular box indicates an order and a rounded box indicates that further identification is needed.


Wings modified, front wings hard or leathery and covering hind wings
Abdomen with cerci-like forceps - DERMAPTERA
Abdomen without cerci-like forceps
Sucking mouth parts, beak usually long
Chewing mouth parts
Front wings without veins, meeting in a straight line down back - COLEOPTERA
Front wings with veins, at rest wings are held roof-like over abdomen or overlapping - ORTHOPTERA
Front wings nearly always thicker at base, membranous at tip; beak comes from front or bottom of head - HEMIPTERA
Front wings of uniform texture throughout; beak comes from hind part of head - HOMOPTERA


All wings are obvious and membranous, but sometimes covered with scales or hairs.
Wings are covered wiht tiny scales; mouth parts are a coiled tube - LEPIDOPTERA
Wings are not covered with scales, usually clear; mouth parts are not a coiled tube
Has 1 pair of wings - DIPTERA
Has 2 pairs of wings
Wings are long, narrow, fringed wiht hairs; 5 mm or less in length - THYSANOPTERA
Wings are not narrowed and fringed; usually over 5 mm in length
Abdomen has 2 or 3 long filaments; hind wings small - EPHEMEROPTERA
Abdomen with short filaments; hind wings larger
Front wings clearly longer and greater in area than hind wings
Wings hairy, opaque; palps long; antennae as long as body or longer - TRICHOPTERA
Wings transparent or translucent, not hairy; palps short or absent; antennae shorter than body
Feet have 5 segments; usually wasp-like or bee-like - HYMENOPTERA
Feet have 2 or 3 segments; not wasp-like or bee-like
Sucking mouth parts, beak at rear of head; small to large - HOMOPTERA
Chewing mouth parts, no beak; 7 mm or less in length - PSOCOPTERA
Front wings not, or just slightly, longer than hind wings, and with same or less area than hind wings
Head prolonged ventrally to form beak-like structure - MECOPTERA
Head not prolonged ventrally
Antennae are very short and bristle-like; large eyes - ODONATA
Antennae are not short and bristle-like; moderate to small eyes
Hind wings are broader than front wings; have cerci - PLECOPTERA
Hind wings are not, or just slightly, broader than front wings; no cerci
Moth-like; wings hairy and opaque; antennae as long as body or longer - TRICHOPTERA
Not moth-like; wings not hairy, usually clear; antennae generally shorter than body
Wings with many cross veins; feet have 5 segments; 75 mm in length - NEUROPTERA
Wings with few cross veins; feet have 4 segments; 8 mm in length - ISOPTERA


Wings are entirely absent
Narrow waist, ant-like - HYMENOPTERA
No narrow waist, not ant-like
Body flattened sideways; small jumping insects - SIPHONAPTERA
Body rarely flattened sideways; usually do not jump
Parasites of birds or mammals; body nearly always flattened sideways
Head as wide as or wider than thorax - MALLOPHAGA
Head narrower than thorax - ANOPLURA
Never parasitic; body usually not flattened
Abdomen with style-like appendages or thread-like tails - THYSANURA
Abdomen with neither styles nor tails
Abdomen with a forked tail-like jumping mechanism - COLLEMBOLA
Abdomen without a jumping mechanism
Abdomen usually with 2 short tubes; small, plump, soft-bodied - HOMOPTERA
Abdomen without tubes; usually not plump and soft-bodied
Lacking pigment, whitish; soft-bodied
Antennae long, hair-like; feet have 2 or 3 segments - PSOCOPTERA
Antennae short, bead-like; feet have 4 segments - ISOPTERA
Distinctly pigmented; usually hard-bodied
Body narrow; less than 5 mm in length - THYSANOPTERA
Body shape variable; length over 5 mm
Antennae have many segments; chewing mouth parts - ORTHOPTERA
Antennae have 4 or 5 segments sucking mouth parts - HEMIPTERA

Three Main Sections of an Insect



Types of Antennae

Setaceous

Filiform

Elbowed

Lamellate

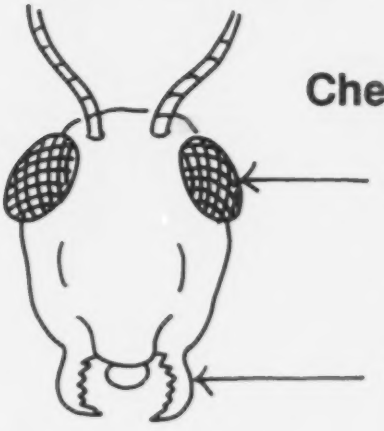
Ringed

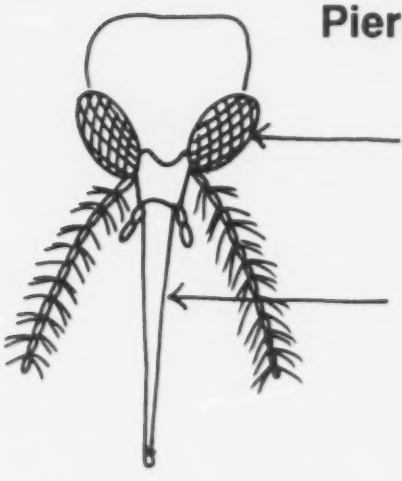
Plumose

Pectinate

Bipectinate

Types of Mouth Parts

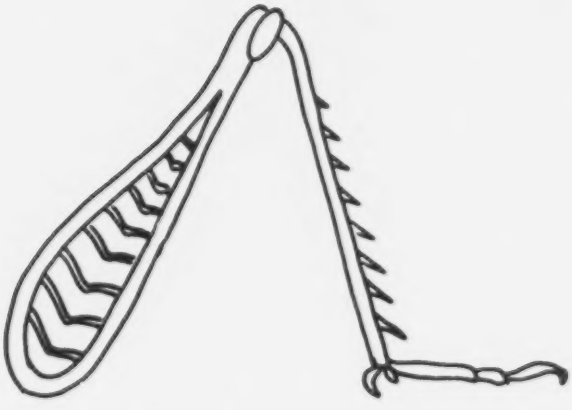




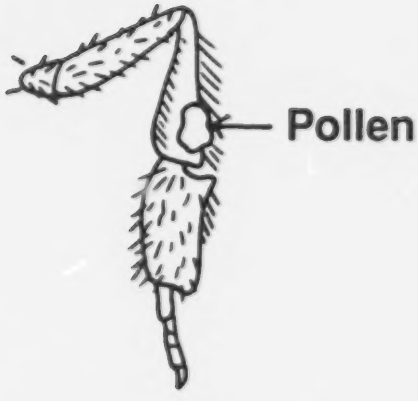
Types of Insect Legs

Swimming leg
(diving beetle)

Jumping leg
(flea)

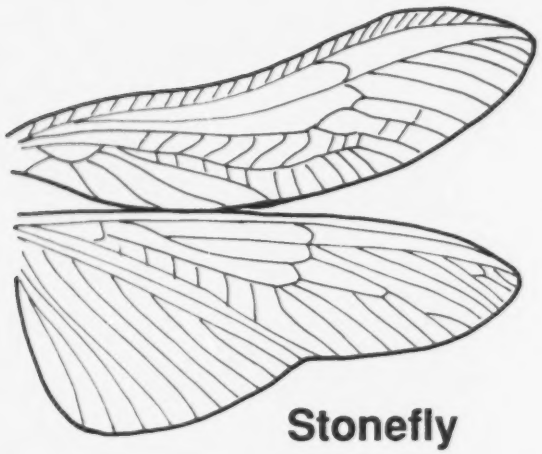


Jumping leg
(grasshopper)

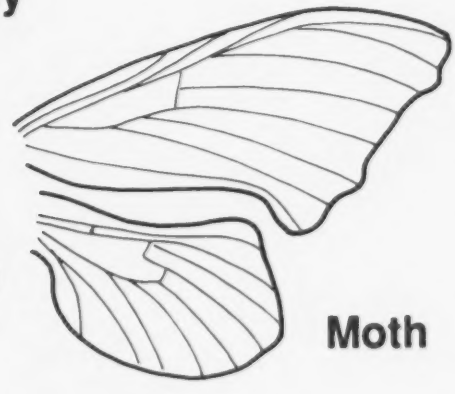


Leg for carrying pollen
(honeybee)

Examples of Wings

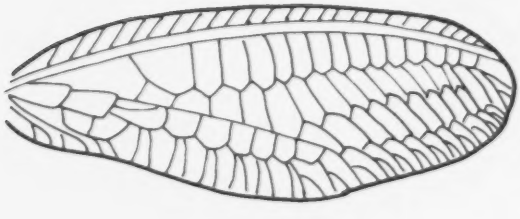


Stonefly

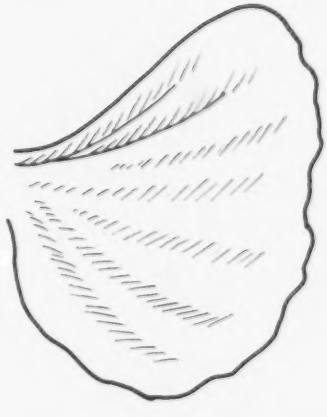


Moth

Housefly

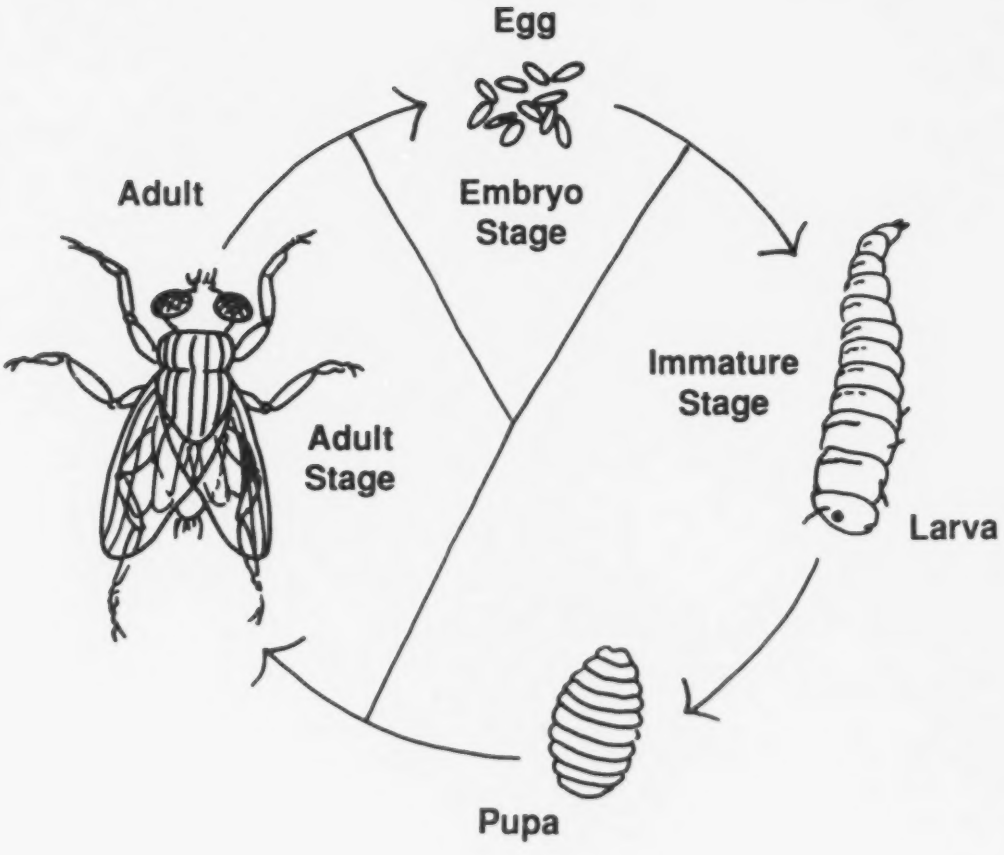


Lacewing

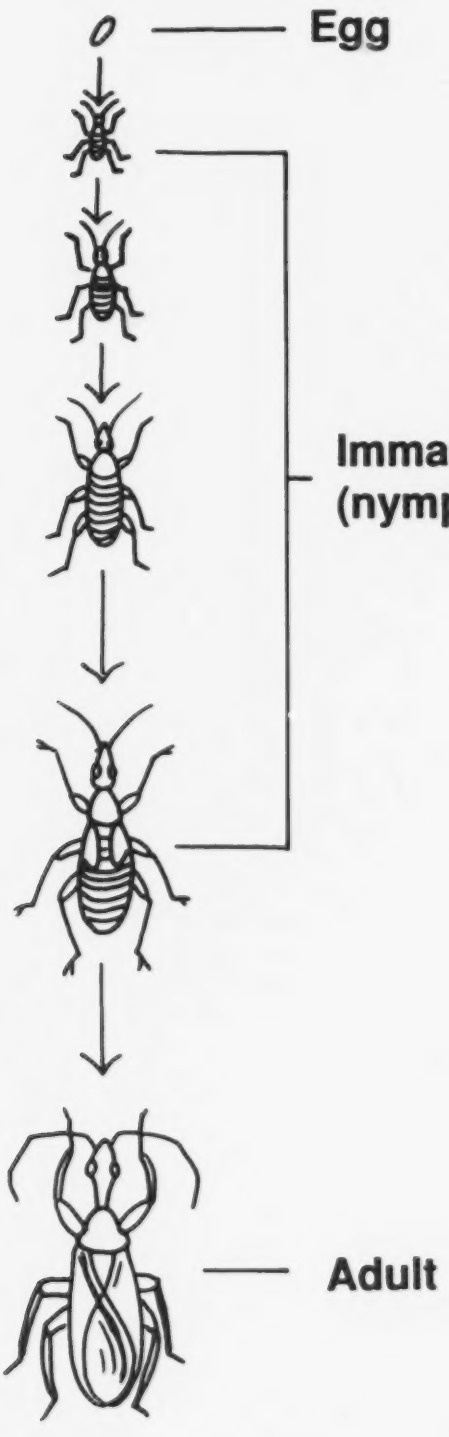


Twisted Parasite

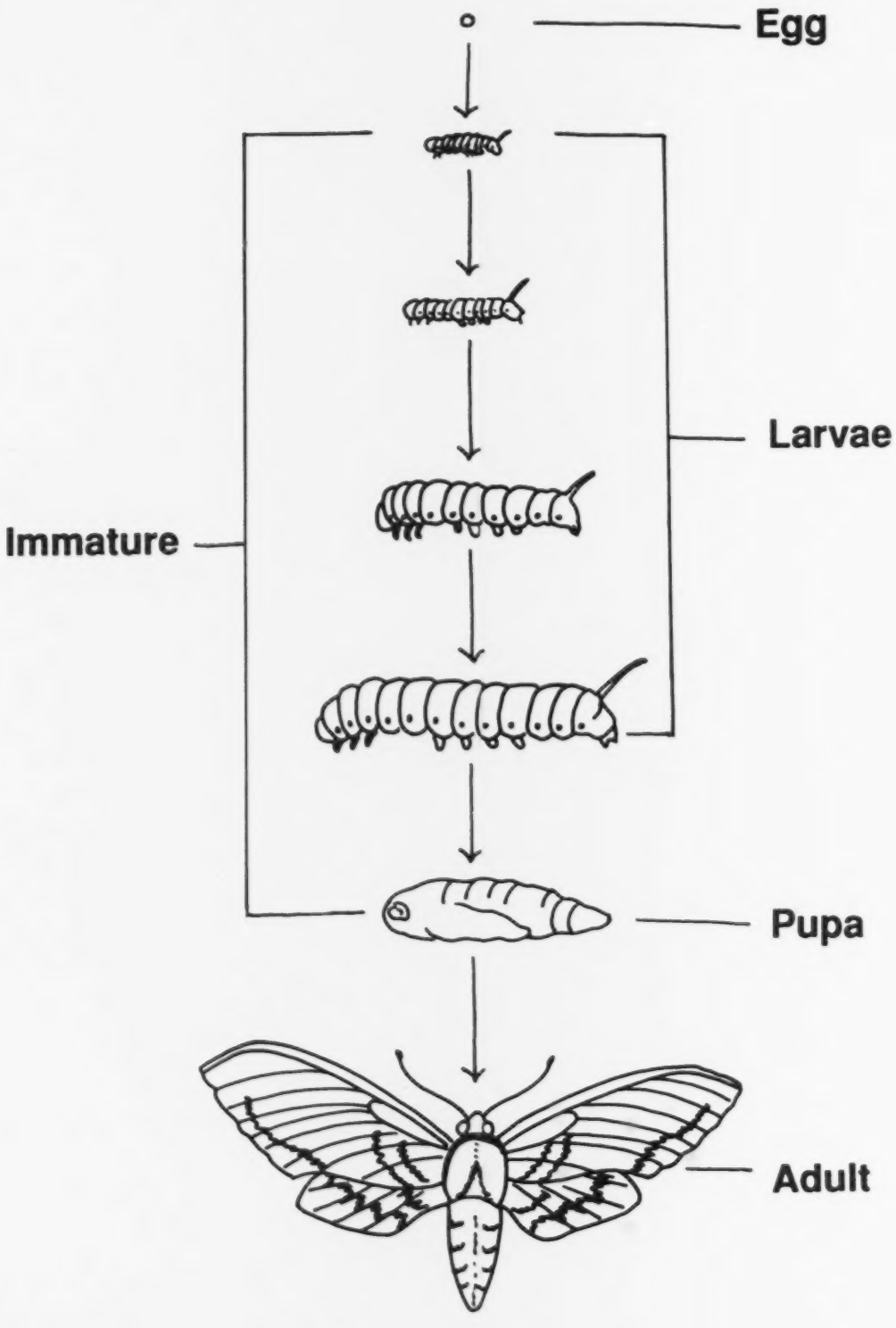
Stages of Development



Incomplete Metamorphosis



Complete Metamorphosis



Insect Classification

Phylum - *Arthropoda*
Class - *Insecta*
Subclass - *Pterygota*
Infraclass - *Neoptera*
Series - *Exopterygota*
Superorder - *Orthopterodea*
Order - *Orthoptera*
Suborder - *Caelifera*
Family - *Acrididae*
Subfamily - *Romaleinae*
Genus - *Romalea*
Species - *microptera*

Example:
Scientific name: *Romalea microptera*
Common name: *Eastern lubber grasshopper*

Lesson 3: Insect Identification

Work Sheet 3.1: Insect Fact Sheet

Fill in the information for the insect selected.

1. Scientific name:
2. Common name:
3. Order:
4. Type of mouth parts:
5. Write a brief description of insect. Identify the features:

   wings:
   color:
   antennae:
   legs:

6. Describe the environment of the insect.

7. What is the insect's natural role in the environment?

8. What type of metamorphosis does the insect have?

9. Describe the life cycle of the insect.

10. How does this insect affect humans and society?

11. Methods of Control:

How is this insect controlled by biological methods?

How is this insect controlled by mechanical methods?

How is this insect controlled by cultural methods?

How is this insect controlled by chemical methods?

12. On what crop would this insect most likely be found?

13. At what time during the growing season does this insect have the greatest effect on the crop?

14. Outline an IPM Plan for this insect. Use the information you have found on the life cycle of the insect and the different control methods.

Lesson 3: Insect Identification

Work Sheet 3.2: Insect Orders

Complete the following chart on the insect orders.

Insect Order	Meaning of Name	Common Name	Type of Metamorphosis	Type of Mouth Part
Phasmida		walking stick or leaf	incomplete	chewing
	equal wings	termites		chewing
	lively wings		incomplete	
Thysanura			none	
		springtails	none	
		beetles		chewing or chewing-lapping
Zoraptera		Zorapterans		
	straight wings		incomplete	
		butterflies, moths	complete	
	long wings			chewing
Neuroptera	nerve wings			
	double tail	campodeids, japygids		
		ants, bees, wasps	complete	chewing or chewing-sucking
Anoplura			incomplete	
Siphonaptera				reduced chewing
		earwigs	incomplete	
		dragonflies, damselflies	incomplete	
Protura		Proturans		
	cricket cockroach	rock crawlers, icebugs		chewing

UNIT - ENTOMOLOGY

Lesson 4: Methods of Control

Objective: The student will be able to describe methods of pest control.

Study Questions

1. **What are the different pest control methods?**
2. **What are the advantages and limitations of biological control methods?**
3. **What are the advantages and limitations of cultural control methods?**
4. **What are the advantages and limitations of physical and mechanical control methods?**
5. **What are the advantages and limitations of chemical control methods?**

Reference

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.

UNIT - ENTOMOLOGY

Lesson 4: Methods of Control

TEACHING PROCEDURES

A. Review

Review the extensive impact insects have on our lives.

B. Motivation

1. Have an insect (e.g., roach, bee, spider, ant, fly) in a jar at the beginning of class. Spray it with a healthy dose of an appropriate insecticide and observe the insect during the class period. A variation of this would be to have two or more jars. These could contain the same type of insect or different types of insects. The same insecticide can be applied to each jar at different rates or different insecticides can be applied. See how long the insecticide takes to kill each insect.

2. Demonstrate the effect and efficiency of the different types of pest control. Show why insect control is necessary. Ask the class to identify various ways to control or kill the common housefly. List answers on the board. Possible answers may include: hitting with hand (cultural control), hitting with fly-swatter (mechanical control), hanging a no-pest strip (mechanical control), screen doors and windows (mechanical control, barrier), spiders as predators (biological control), household insecticide spray (chemical control), and outdoor light zappers (mechanical). Identify the form of pest control demonstrated by each answer. Discuss the risks and benefits of each method. Discuss how the various methods can be combined and when one might consider each type of method.

C. Assignment

This lesson will enable students to complete Question 11, Methods of Control, on their Insect Fact Sheets (WS 3.1).

D. Supervised study

E. Discussion

1. Insects have a great influence on many aspects of our lives. People compete with insects for food, fiber, and health in many areas. The control and management of insects is an important part of one's life as well.

What are the different pest control methods?

a) There are different ways to control insects.
   1) Biological control methods
   2) Cultural control methods
   3) Physical and mechanical control methods
   4) Chemical control methods

b) The particular method or methods selected depend on the needs of the individual.

2. Biological control is the use of naturally occurring organisms to control insects. These include: bacteria, diseases, fungi, viruses, insects, nematodes, birds, fish, toads and frogs, lizards, snakes, rodents, and weeds.

What are the advantages and limitations of biological control methods?

a) Four general areas of biological control
   1) Using the insect's natural enemies - selectively increasing the population of the insect's natural enemies
   2) Resistant plant varieties - using plant varieties, occurring naturally and by genetic research, that are resistant to the insect
   3) Crop rotations - rotating the type of crop grown in a particular spot so that the same crop is not grown continuously
   4) Sterilization - using chemicals or radiation to sterilize or to genetically alter insects so they cannot reproduce

b) Advantages
   1) Works with the insect's natural enemies and environment
   2) Not necessarily expensive

c) Limitations
   1) Only partially effective
   2) Requires a lot of time to become effective
   3) Results are not guaranteed
   4) Not easy to control insects selectively
   5) An extensive knowledge of the insect's life cycle and response to the environment is necessary.
   6) Can be labor intensive
   7) Can be very expensive
   8) Not practical for commercial agriculture
   9) Cannot predict effect on the environment

3. Cultural control is the management of insect populations by modifying the environment. Standard production practices are used to make the environment less attractive or agreeable for insects.

What are the advantages and limitations of cultural control methods?

a) Five methods in cultural control
   1) Tillage systems
   2) Crop rotation
   3) Sanitation
   4) Timing of harvest and planting
   5) Water management

b) Advantages
   1) Does not require special machinery or equipment
   2) Uses standard agricultural or management practices
   3) Is not expensive
   4) Most practices do not require intensive labor

c) Limitations
   1) Only partially effective
   2) Not easy to control insects selectively
   3) An extensive knowledge of the insect's life cycle and responses to the environment is necessary.
   4) Can be labor intensive

4. Ask students how they physically or mechanically destroy insects.

What are the advantages and limitations of physical and mechanical control methods?

a) Physical and mechanical control methods
   1) Directly destroying insects
   2) Modifying the environment to make it unsuitable for insect pests
   3) Differ from cultural methods because, in addition to normal production practices, special machinery and equipment are used.

b) Advantages
   1) Results are immediate and noticeable.
   2) Based on standard agricultural or management practices

c) Limitations
   1) Only partially effective
   2) Not easy to control insects selectively
   3) An extensive knowledge of the insect's life cycle and responses to the environment is necessary.
   4) Can be labor intensive
   5) Can be expensive
   6) Limited application in commercial agriculture

5. Ask students about the kinds of insecticides with which they are familiar.

What are the advantages and limitations of chemical control methods?

a) Classification of insecticides
   1) Organic insecticides - manufactured materials consisting mainly of carbon, hydrogen, and oxygen
      (a) Chlorinated Hydrocarbon - also called organic chlorines
      (b) Organic Phosphate - contains phosphorus
      (c) Carbamate - contains groups of nitrogen and hydrogen
   2) Inorganic insecticides - are made from minerals, are persistent, and do not break down easily in the environment
   3) Botanical insecticides - are made from plants
      (a) Nicotine
      (b) Potenome
      (c) Dried pyrethrum flowers
   4) Bacterial insecticides - infect insects with diseases; specifically kills one kind of insect; used on Japanese beetles and caterpillars

b) Advantages
   1) Works quickly and effectively
   2) Possible to control a particular insect selectively
   3) Only a general knowledge of the insect's life cycle and responses to environment is needed.
   4) Not labor intensive

c) Limitations
   1) Buildup of insecticide-resistant insects
   2) Outbreaks of other harmful insects
   3) May have negative effects on the environment if not used properly
   4) Extremely dangerous to people

NOTE: Discuss how the different methods of insect control may be used together for different situations. Encourage students to think about what is involved with each method and to compare the strengths and weaknesses of each. There are no real "right" or "wrong" answers. A person skilled

in insect control needs to be able to use a variety of control methods. The following questions provide a starting point for the discussion.

1. Which methods are most appropriate for commercial agriculture?
2. Which methods are best suited for home and garden care?
3. Which methods should be selected if insect control is needed immediately? Why?
4. Why is the timing of insect control important?
5. Why are labor intensive methods considered a limitation?
6. Why is it necessary to consider the level of knowledge needed for activating a particular control method?
7. How can the different methods be used together?
8. Which methods would not work well together?

F. Other activity

Bring in different types of common household or garden insecticides. Have the students compare the labels for the amount of time necessary for effective use, types of insects killed, restrictions for use, and any harmful side effects to the environment.

G. Conclusion

There are several different methods for controlling insects. Each has its own advantages and limitations. The particular method or methods chosen depend on the needs of the individual. Frequently, more than one method is used for the best control of insects.

H. Competency

Describe methods of pest control.

I. Answers to Evaluation

1. c
2. b
3. a
4. a
5. d
6. d
7. d
8. c
9. b
10. Evaluate the responses based on what was discussed in class.

UNIT - ENTOMOLOGY Name _____

Lesson 4: Methods of Control Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What are the four groups of insect control methods?

   a. Cultural, environmental, physical, and chemical
   b. Biological, cultural, environmental, and genetic
   c. Biological, cultural, physical and mechanical, and chemical
   d. Physical and mechanical, chemical, insecticides, and biological

2. What are the four areas of biological control?

   a. Natural enemies, resistant varieties, tillage systems, sterilization
   b. Natural enemies, resistant varieties, crop rotations, sterilization
   c. Resistant varieties, crop rotations, sanitation, tillage systems
   d. Organic phosphates, crop rotations, tillage systems, sterilization

3. How is physical and mechanical control different from cultural control?

   a. Physical and mechanical control uses special machinery or equipment in addition to standard production practices.
   b. Physical and mechanical control uses special machinery or equipment instead of standard production practices.
   c. Physical and mechanical control uses special chemicals in addition to standard production practices.
   d. Physical and mechanical control uses special machinery or equipment in addition to standard chemical control.

4. How can removing weeds and crop residues help control insects?

   a. Removes a favorable living environment for insects
   b. Attracts insects that spread to crop plants
   c. Keeps insects alive between crop plantings
   d. Provides an underground haven for insects

5. Which of the following does <u>not</u> involve the timing of insect control to reduce insect populations?

   a. Insects can be destroyed before they complete their life cycle.
   b. Insect reproduction can be inhibited or prevented.
   c. Insect food sources can be limited and their numbers reduced.
   d. Insects can be sprayed with insecticides.

6. Which of the following is an advantage of crop rotation?

   a. Changing the host species and environment increases insect population build up.
   b. Involves a higher level of management skills.
   c. Especially effective with insects that are very mobile.
   d. Disrupts the life cycle of the insect.

7. Why is the amount of labor necessary for a particular control method important?

   a. An individual must consider the cost of additional labor.
   b. Control measures may need to be done within a certain amount of time.
   c. Seasonal labor may not be available at the needed time.
   d. All of the above

8. What are the three groups of organic insecticides?

   a. Inorganics, botanicals, and bacterials
   b. Bacterials, organic phosphates, and carbamates
   c. Chlorinated hydrocarbons, organic phosphates, and carbamates
   d. Nicotines, chlordanes, and malathions

9. When are chemical insecticides most likely to be harmful to the environment?

   a. When they are extremely dangerous
   b. When they are not applied properly
   c. When they enter the environment very quickly
   d. When they are persistent and are not very easily broken down in the environment

Complete the following short answer question.

10. What are the advantages and limitations of using different control methods together?

UNIT - ENTOMOLOGY

Lesson 5: Chemical Control Methods

Objective: The student will be able to describe the factors in the selection and application of insecticides.

Study Questions

1. **What are pesticides?**
2. **When is an insect considered a pest?**
3. **What are the different types of pesticides?**
4. **What is the mode of action for different types of insecticides?**
5. **What are methods of insecticide application?**
6. **What are the different formulations of insecticides?**
7. **How are insecticides applied?**
8. **Why is it important to calibrate a sprayer accurately?**

Reference

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.

UNIT - ENTOMOLOGY

Lesson 5: Chemical Control Methods

TEACHING PROCEDURES

A. Review

Biological, cultural, physical and mechanical, and chemical are the different methods of insect control. Each method has its own advantages and limitations. All factors need to be considered when selecting an insect control plan. Often, a combination of methods is used for insect control.

B. Motivation

Have several containers of common household chemicals on display. The containers could be from home, a drugstore, a grocery, or a gardening supply store. Compare the information (e.g., ingredients, mode of action, safety precautions) on the labels.

C. Assignment

D. Supervised study

E. Discussion

1. Pesticides are an important part of any insect control plan. Point out that insecticides are pesticides that are specifically made for controlling insects.

   What are pesticides?

   The term pesticide is a general term used for any chemical used to kill any pest.

2. Discuss with students when an insect is considered a pest and when it is considered a beneficial insect.

   When is an insect considered a pest?

   Insects are considered pests when they compete with humans for food and fiber or attack people directly.

3. Pesticides are classified by the types of pests they are designed to control. The pest for which a pesticide is intended is called the target pest. The target pests are listed after the type of pesticide. Chemical control methods are often used to control harmful insects because they are very effective, easy to apply, quick acting, usually economical, target specific, and practical for commercial use.

   What are the different types of pesticides?

   a) Acaricide - mites and ticks
   b) Avicide - birds
   c) Bactericide - bacteria
   d) Fungicide - fungi
   e) Herbicide - weeds
   f) Insecticide - insects

g) Miticide - mites
h) Molluscicide - snails and slugs
i) Nematicide - nematodes
j) Piscicide - fish
k) Rodenticide - rodents (rats and mice)

4. How an insecticide works is called the mode of action. Encourage students to discuss in what insect control situations would the different modes of action be the most effective.

What is the mode of action for different types of insecticides?

a) Contacts
b) Systemics
c) Fumigants
d) Protectants
e) Sterilants
f) Selective insecticides
g) Nonselective insecticides
h) Growth regulators
i) Biologicals

5. Discuss the importance of applying an insecticide using the proper method. Point out that some insecticides may not work if applied by the wrong method.

What are methods of insecticide application?

a) Pre-emergence
b) Preplant
c) Band
d) Broadcast
e) Dip
f) Directed
g) Drench
h) Foliar
i) In-furrow
j) Over-the-top
k) Pour-on
l) Sidedress
m) Soil incorporation
n) Spot treatment

6. An insecticide formulation refers to the specific way the product is made. Students can be asked for examples of each of these formulations. Insecticides are made and applied as a liquid, gas, or solid. Most formulations have a letter abbreviation.

What are the different formulations of insecticides?

a) Liquid formulations
    1) Emulsifiable concentrate (EC or E)
    2) Flowables (F or L)
    3) Solutions (S)
    4) Ultra-low-volume solutions (ULV)
    5) Aerosols (A)
    6) Liquified gases

b) Dry formulations
   1) Dusts (D)
   2) Granules (G)
   3) Soluble powders (SP)
   4) Wettable powders (WP or W)
   5) Baits (B)

7. How insecticides are applied depends on the formulation. If possible, sprayer and nozzle types can be shown as visual aids. Insecticides may be sprayed, dusted, used in a dipping tank, injected, or mixed with insect food. The application equipment, which depends on the insecticide formulation, is very important for proper application of insecticides.

How are insecticides applied?

a) Sprayers
   1) Hand sprayers
   2) Low-pressure field sprayers
   3) High-pressure sprayers
   4) Air-blast sprayers
   5) Ultra-low-volume (ULV) sprayers

b) Nozzle types
   1) Solid stream
   2) Flat fan
   3) Hollow cone
   4) Solid cone
   5) Broadcast

8. Calibrating a sprayer means adjusting the equipment so that the insecticide is applied at the desired rate.

Why is it important to calibrate a sprayer accurately?

a) It is important to accurately calibrate a sprayer so that each insecticide is used as directed on the label.
b) The best results are obtained by correct calibration. Too much insecticide is dangerous, costly, and wasteful. Too little insecticide will not do an effective job.

NOTE: There are several ways to calibrate sprayers, depending on the equipment used and personal preference. Several ways are presented in Appendix A. Stress the importance of always taking the time to calibrate and check equipment.

F. Other activities

1. Have students visit an equipment shop or supply store to see the different kinds of insecticides, application equipment (e.g., sprayers, nozzles), and calibration charts.

2. Have students take home problems on calibrating sprayers.

3. Invite a custom insecticide applicator or insecticide dealer to demonstrate how to calibrate a sprayer. If the shop doesn't have the appropriate equipment, ask the individual to bring it for the demonstration.

G. Conclusion

Chemical insecticides are commonly used as part of an effective insect control plan. There are many kinds of chemicals from which to choose. Each works in its own particular way. It is very important to select the insecticide formulation and equipment that is most appropriate for the job. Insecticides must be properly applied and the equipment accurately calibrated for effective and safe insect control.

H. Competency

Describe the factors in the selection and application of insecticides.

I. Answers to Evaluation

1. A pesticide is a general term for any chemical used to kill any pest, whereas an insecticide refers to chemicals that specifically kill insects.

2. Any 6 of the following: contacts, systemics, fumigants, protectants, sterilants, selective insecticides, non-selective insecticides, growth regulators, biologicals

3. Any 6 of the following: pre-emergence, preplant, band, broadcast, dip, directed, drench, foliar, in-furrow, over-the-top, pour-on, sidedress, soil incorporation, spot treatment

4. b
5. c
6. c
7. d
8. a
9. b
10. b

80

UNIT - ENTOMOLOGY Name _____

Lesson 5: Chemical Control Methods Date _____

EVALUATION

Complete the following short answer questions.

1. What is the difference between a pesticide and an insecticide?

2. Name 6 ways insecticides work (mode of action).

3. Name 6 terms used to describe the methods of insecticide application.

Circle the letter that corresponds to the best answer.

4. When are insects not considered pests?

   a. When they compete with humans for food, fiber, or health
   b. When they destroy other insects that eat crop plants
   c. When they tunnel or bore into stems, stalks, roots, and branches
   d. When they suck the sap from leaves, stems, roots, fruits, and flowers

5. Which of the following is not a consideration when selecting the insecticide formulation?

   a. The type of coverage needed
   b. The type and condition of the target plant or animal
   c. The calibration of the equipment
   d. The formulation

6. What is the key to using insecticides effectively?

   a. Selecting the right insecticide formulation
   b. Calibrating the sprayer accurately
   c. Following the directions on the label
   d. Selecting the best nozzle type

7. What is the purpose of the inactive, or inert, ingredient in an insecticide formulation?

   a. These materials activate the active ingredient.
   b. These materials are the chemicals that kill the insects.
   c. These materials bring the mass of the bag to the proper weight.
   d. These materials make the active ingredient easier to apply.

8. Why are weather conditions important when applying insecticides?

   a. Weather conditions can change the effectiveness of insecticides.
   b. Rain can help spread the insecticide around for greater coverage.
   c. Winds help spread the insecticide for greater coverage.
   d. Rain can help insecticides soak into the ground.

9. Which of the following would <u>not</u> change the rate of insecticide delivered to an area?

   a. Change in the pressure
   b. Change in the tank volume
   c. Change in speed
   d. Change in the nozzle tips

10. Why is it important to calibrate a sprayer properly?

   a. Sprayers do not need to be properly calibrated.
   b. Each insecticide must be applied as directed on the label.
   c. Applying too much insecticide can increase insect resistance.
   d. Applying too little insecticide can pollute the soil.

UNIT - ENTOMOLOGY

Lesson 6: Safe Use of Insecticides

Objective: The student will be able to identify safety guidelines for insecticide use.

Study Questions

1. **What information is located on an insecticide label?**
2. **How is insecticide toxicity measured?**
3. **What certifications are required for pesticide applicators?**
4. **What are the safety guidelines for using insecticides?**
5. **What are the safe ways to dispose of insecticides and insecticide containers?**
6. **What are symptoms of insecticide poisoning?**
7. **What are the correct first aid procedures for insecticide poisoning?**
8. **What supplies should be included in a first aid kit?**
9. **Where is the nearest poison control center?**

References

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.
2. U.S. Department of Agriculture and U.S. Environmental Protection Agency. Applying Pesticides Correctly, A Guide for Private and Commercial Applicators. U.S. Department of Agriculture and U.S. Environmental Protection Agency, n.d. (teacher reference only)
3. University Extension agricultural publications, University of Missouri Columbia: (teacher reference only)
   a) GO1915: First Aid for Pesticide Poisoning
   b) GO1916: Pesticide Application Safety
   c) GO1917: Personal Protective Equipment for Working with Pesticides
   d) GO1918: Homeowner Chemical Safety
4. Work Sheet
   a) WS 6.1: Reading an Insecticide Label

UNIT - ENTOMOLOGY

Lesson 6: Safe Use of Insecticides

TEACHING PROCEDURES

A. Review

Chemical control is a part of almost all insect control plans, because it is very effective and relatively inexpensive. Since most insecticides are toxic to humans, animals, and/or the environment, it is important to read and follow label directions exactly. Federal and state laws regulate how insecticides should be applied and on what plants and animals they can be applied.

B. Motivation

1. Have students compare the label of several different types of insecticides. Work Sheet 6.1 can be used to help stimulate questions.

2. Demonstrate the various types of protective clothing and equipment.

3. Ask the class to identify how insecticides affect our everyday lives, both positively and negatively. Topics could include: environmental activities, safety precautions for insecticide use, and insecticides required to produce and preserve food and fiber for society.

C. Assignment

D. Supervised study

E. Discussion

1. Discuss with students the information found on a insecticide label. The instructor may want to point out the information on several different insecticide labels. Have students complete WS 6.1, Reading an Insecticide Label.

What information is located on an insecticide label?

a) Type of insecticide
b) Target insects
c) Application techniques
d) How the product affects different plants and animals
e) Toxicity level
f) Signal words
g) Safety guidelines
h) Disposal methods
i) First aid procedures

2. Discuss with students how insecticide toxicity is measured. Discuss with students why it is important to measure the toxicity level of insecticides.

How is insecticide toxicity measured?

a) LD_{50} is a standard measure of toxicity.
   1) "LD" stands for the "lethal dose" of the insecticide. This is expressed in milligrams

of insecticide per kilogram of animal body weight necessary to kill half of the population of test animals (such as mice, guinea pigs, rabbits) within two weeks.

2) The lower the LD number, the greater the insecticide toxicity and the less it takes to kill.

b) Signal words are used to indicate the level of toxicity and precautions for the product. They are located directly below the statement "Keep Out Of The Reach Of Children."

1) Class I. DANGER or DANGER-POISON with an accompanying drawing of a skull and crossbones
   (a) Letters printed in red
   (b) Highly toxic category
   (c) Oral LD_{50} rating of 0-50
2) Class II. WARNING
   (a) Moderately toxic category
   (b) Oral LD_{50} rating of 50-500
3) Class III. CAUTION
   (a) Slightly toxic category
   (b) Oral LD_{50} rating of 500-5,000

3. Discuss with students what certifications are required for pesticide applicators. Give information about the place where students can obtain the certification.

What certifications are required for pesticide applicators?

a) There are two classifications of pesticides. Some pesticides may be a combination of the two. The classification is listed on the product label.

1) "General use" pesticides are not likely to harm people, wildlife, and/or the environment when used according to label directions.
   (a) Examples are Malathion®, Sevin®, and Pyronone®.
   (b) Certification is not required.
2) "Restricted use" pesticides could cause serious injury to people, wildlife, or the environment unless applied by a well-trained and competent pesticide applicator, or under the direct supervision of such an applicator.
   (a) Examples are Lannate®, Nicotine® and Thiodan®.
   (b) Certification is required.

b) There are two main categories of certified pesticide applicator's licenses.

1) Private applicator
   (a) Administer restricted use pesticides onto their own land, onto land they rent, or onto property of a person with whom they trade services
   (b) Receive training in pesticide application
   (c) Common type of license for most producers
   (d) License valid for five years and then must be renewed
2) Commercial applicator
   (a) Apply restricted use pesticides on the property of others
   (b) Receive training in pesticide application as well as specialized training
   (c) License valid for three years and then must be renewed

4. Discuss with students safety guidelines for using insecticides. Emphasize how important it is to read and follow all insecticide label directions. More information can be found in University Extension Guide #G01917, "Personal Protective Equipment for Working with Pesticides."

What are the safety guidelines for using insecticides?

a) Always read and follow label directions EXACTLY.

b) Remove all people, pets, and foodstuffs prior to insecticide application.
c) When spraying in an enclosed environment, close all doors, vents, and openings before applying insecticides in order to avoid insecticide drift.
d) Never smoke, eat, or drink while applying insecticides.
e) Always wear protective clothing and use protective equipment to prevent exposure to external irritant insecticides.
    1) Wear clean long trousers and a long-sleeved shirt, or coveralls made of closely woven cloth.
    2) Wear unlined rubber gloves and rubber boots made of neoprene.
    3) Wear shirt sleeves outside of the gloves and wear pant legs outside of the boots to prevent pesticides from entering.
    4) Wear close-fitting eye goggles or a face shield.
    5) Wear a wide-brimmed waterproof hat, one that is easy to clean or is disposable.
    6) Wear a respiratory device that prevents internal poisoning whenever applying an insecticide.
    7) Clean clothing and equipment as directed by the insecticide label or by the poison control center recommendations.
f) Always wear a respiratory device approved by an appropriate agency (NIOSH and MSHA) to prevent internal poisoning.
    1) Cartridge respirator - used for occasional exposure to most insecticides.
    2) Gas mask or canister respirator - used when the applicator is exposed to an insecticide for a relatively long period of time or is exposed to high concentrations of insecticides for a short period of time, and working in a confined or closed area.
    3) Self-contained breathing apparatus - used if the oxygen supply is low or the insecticide vapor concentration is high.
g) Always take precautions to avoid insecticide drift.
h) Shower and shampoo after applying insecticides.
i) Wash clothing exposed to insecticide separately from other clothing or if disposable, dispose of properly.
j) Maintain a health watch program with a physician if applying insecticides on a regular basis.
    1) Inform the doctor of the exact insecticides used so he or she can review chemical formulations and stock a supply of antidotes.
    2) Follow special instructions for persons applying carbamate or organophosphate insecticides.
        (a) Establish a regular cholinesterase testing program with doctor.
        (b) Have a "baseline" test taken in January.
        (c) Have periodic follow-up tests for cholinesterase level - if cholinesterase level falls too low, the doctor will limit or stop applicator's contact with these two insecticides until level returns to normal range.

5. Discuss with students the safe ways to dispose of insecticides and insecticide containers. More information can be found in the MU guide #G01916, "Pesticide Application Safety." For help with safe disposal of insecticides and/or insecticide containers, contact the Missouri Department of Natural Resources.

What are the safe ways to dispose of insecticides and insecticide containers?

a) Read and follow insecticide container label instructions and/or precautions for disposal.
b) Apply any surplus insecticide to other areas with the same pest problem.
c) Never flush insecticides down the drain, into sewers, or into waterways.
d) Take unwanted insecticides and/or insecticide containers to a toxic waste disposal landfill.

e) Follow these general guidelines for insecticide disposal established by the U.S. Department of Agriculture and the U.S. Environmental Protection Agency.
   1) Never leave surplus insecticides and/or insecticide containers at the application site.
   2) Never reuse insecticide containers.
   3) Keep all insecticide containers out of the reach of children.
   4) Store leftover insecticides in tightly covered containers in a safe storage facility until they can be disposed.

f) For help with safe disposal of insecticides, contact:
   Missouri Department of Natural Resources
   Division of Environmental Quality
   P.O. Box 176
   Jefferson City, Missouri 65102
   Business phone: 314-751-7929
   Emergency response phone: 314-634-2436

6. Discuss with students the symptoms of insecticide poisoning. Point out that there are no standard symptoms.

What are symptoms of pesticide poisoning?

a) There are no standard symptoms of insecticide poisoning. Symptoms vary depending on several factors.
   1) Kind and amount of insecticide
   2) Length of exposure
   3) Time interval between exposures
   4) General health of the victim

b) There are two categories of insecticide poisoning. Many insecticides fit in both categories.
   1) External irritants - those which sting the nose, eyes, ears, throat, and mouth due to insecticide splashing on external tissues
   2) Internal poisons - those which injure body organs due to insecticide being taken into the body through the mouth or skin

7. Discuss with students the correct first aid procedures for insecticide poisoning. More first aid information can be found in the MU guide #G01915, "First Aid for Pesticide Poisoning."

What are the correct first aid procedures for insecticide poisoning?

a) Act as quickly as possible.
b) Without endangering yourself, remove the victim from the contaminated area.
c) Remove contaminated clothing from the victim.
d) Generously flood the affected skin area or eye with water.
e) Contact the Poison Control Center or a doctor.
f) Administer first aid as indicated by Poison Control Center Personnel or doctor.

NOTE: If an insecticide accident occurs at school, the instructor should notify the school nurse as soon as possible.

8. Discuss with students the importance of having a first aid kit available.

What supplies should be included in a first aid kit?

a) Adhesive tape

b) Assorted bandages
c) Blanket
d) Merthiolate
e) Syrup of ipecac
f) Teaspoon
g) Two quarters (for phone calls)

NOTE: It is crucial that the school shop have a complete first aid kit available. Poison Control Center personnel or a doctor will indicate first aid procedures that need to be followed.

9. Discuss with students information about the nearest poison control center. The instructor should post the toll-free number by the telephone, so it is handy in the event of insecticide poisoning.

Where is the nearest poison control center?

a) Missouri's center is staffed 24 hours by medical professionals.
Missouri Regional Poison Control Center
Cardinal Glennon Memorial Hospital
1465 South Grand Avenue
St. Louis, Missouri 63104
Telephone: **1-800-392-9111**

b) It is important to have the insecticide label with you when talking with the Poison Control Center.

F. Other activities

1. Visit a local farm or garden supply store to see their insecticide application equipment, including respirators and protective clothing. Require students to take notes on their observations. Students may be asked to prepare a written report on the field trip.

2. Show the audiovisual materials for private pesticide applicator's license from University Extension.

3. Students may participate in the training session required for a private pesticide applicator's license.

4. Invite an extension agent or other specialist to talk about insecticide safety.

5. Have students write to one of the following for more information about insecticides.

a) Occupational Safety and Health Administration (OSHA)
Regional Office: 911 Walnut Street
Kansas City, MO 64106
Telephone - 816-374-5861
St. Louis Office: 4300 Goodfellow
St. Louis, MO 63120
Telephone - 314-263-2749
Nationwide toll-free telephone - 1-800-392-7743

b) National Institute for Occupational Safety and Health (NIOSH)
200 Independence Avenue SW
Washington, D.C. 20201
Telephone - 202-472-7134

c) Mine Safety and Health Administration (MSHA)
4015 Wilson Blvd.
Arlington, VA 22203
Telephone - 703-235-1385

G. Conclusion

Insecticide applicators must know and practice the principles of safe insecticide use in order to protect themselves, animals, and/or the environment from the effects of toxic insecticides. Always read and follow all insecticide label directions.

H. Competency

Identify safety guidelines for insecticide use.

I. Answers to Evaluation

1. b
2. a
3. c
4. d
5. d
6. b
7. a
8. b
9. c
10. External irritants - such as stinging of nose, eyes, ears, throat, and mouth due to insecticide splashing on external tissues
Internal poisons - such as injury to body organs due to insecticide being taken into the body through the mouth or skin

J. Answers to Work Sheet 6.1

The instructor will need to determine if answers are appropriate.

UNIT - ENTOMOLOGY Name_____

Lesson 6: Safe Use of Insecticides Date_____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is the most important thing to remember when working with insecticides?

   a. Wear protective clothing.
   b. Read and follow label directions.
   c. Apply insecticides only when needed.
   d. Work with insecticides away from animals and waterways.

2. Which signal word represents the moderately toxic insecticide category?

   a. WARNING
   b. CAUTION
   c. DANGER
   d. BEWARE

3. Which of the following is correct?

   a. The higher the LD number, the greater the insecticide toxicity and the less it takes to kill.
   b. The lower the LD number, the lower the insecticide toxicity and the more it takes to kill.
   c. The lower the LD number, the greater the insecticide toxicity and the less it takes to kill.
   d. The higher the LD number, the greater the insecticide toxicity and the more it takes to kill.

4. What is the most important rule when applying first aid to an insecticide poisoning victim?

   a. Check for shock symptoms
   b. Flood victim and area with water.
   c. Remove contaminated clothing
   d. Act immediately to begin first aid procedures

5. Why is it important to wear a respiratory device when using insecticides?

   a. To protect the applicator's eyes from fumes
   b. To prevent external poisoning
   c. It is not usually important to wear a respiratory device
   d. To prevent internal poisoning

6. Which type of certified pesticide applicator's license would most farmers applying insecticides hold?

   a. Commercial
   b. Private
   c. Federal
   d. General use

7. What agency establishes the guidelines for the disposal of insecticides?

   a. Environmental Protection Agency
   b. Extension Service
   c. Department of Natural Resources
   d. Federal Insecticide, Fungicide, and Rodenticide Act

8. What does a classification of "restricted use" of an insecticide indicate?

   a. The insecticide is not likely to harm people, wildlife, and/or the environment when used according to label directions.
   b. The insecticide could cause serious injury to people, wildlife, or the environment unless applied by a well-trained and competent insecticide applicator.
   c. The applicator does not need to be certified.
   d. The insecticide can only be used on certain crops.

9. Which of the following would <u>not</u> be a correct first aid procedure for insecticide poisoning?

   a. Act as quickly as possible.
   b. Without endangering yourself, remove the victim from the contaminated area.
   c. Induce vomiting as quickly as possible.
   d. Generously flood the affected skin area or eye with water.

Complete the following question with a short answer.

10. What is the difference in the two categories of insecticide poisoning: external irritants and internal poisons?

Lesson 6: Safe Use of Insecticides

Work Sheet 6.1: Reading an Insecticide Label

Look at the label on any product containing insecticide and answer the following questions.

1. What is the common name of the product?

2. What is this product used for?

3. What is the name of the insecticide in this product?

4. What is the active ingredient?

5. What other ingredients does this product contain?

6. What is the formulation type?

7. How is the product applied?

8. What is the recommended dosage?

9. Are there any restrictions on usage?

10. What instructions are given in case of poisoning?

UNIT - ENTOMOLOGY

Lesson 7: Integrated Pest Management

Objective: The student will be able to outline an IPM plan.

Study Questions

1. **What is IPM (Integrated or Insect Pest Management)?**
2. **Why is IPM important?**
3. **What does the economic threshold indicate?**
4. **What steps are involved in developing an IPM plan?**
5. **What is a crop calendar?**

Reference

1. Entomology (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1991.

UNIT - ENTOMOLOGY

Lesson 7: Integrated Pest Management

TEACHING PROCEDURES

A. Review

Give an overview of Lessons 1-6. Discuss how all the information works together. Lesson 7 shows how the information is integrated together to develop an insect control plan.

B. Motivation

Students should review the information they have prepared for their individual insects. Have students think about ways that they would control their insects if they become a problem.

C. Assignment

Students are to complete their individual insect projects (WS 3.1) by developing an IPM plan using the information they have already prepared.

D. Supervised study

E. Discussion

1. Discuss why insect management is an important part of one's life.

What is IPM (Integrated or Insect Pest Management)?

The letters "IPM" are used to refer to two different programs. The most general program is Integrated **P**est **M**anagement. If the pest in question is specifically insects, then the letters can stand for **I**nsect **P**est **M**anagement.

2. Discuss why IPM is important. Explain what the economic injury level (EIL) is.

Why is IPM important?

The basic goal in insect pest management is to prevent insect populations from attaining the **economic injury level (EIL).** The economic injury level is the level of damage insects do to a crop that is equal in value to the cost it requires to use measures that suppress the insects.

3. Discuss why it is not always necessary to start insect control measures when insects are seen on a crop.

What does the economic threshold indicate?

The economic threshold indicates the level of damage done by an insect that is used to warn the agriculturalist of potential problems.

4. List and describe the specific steps in developing an IPM plan.

What steps are involved in developing an IPM plan?

1) Identify the problem
2) Assess the damage
3) Prepare cost/benefit analysis
4) Select a management strategy
5) Implement the management strategy
6) Follow-up on the plan

5. Discuss why an Integrated Pest Management program begins by focusing on the crop. The different management plan possibilities can be better evaluated by making a crop calendar.

What is a crop calendar?

A crop calendar is an outline of the crop's growing season. It provides a systematic and efficient way of looking at the components in a cropping system.

a) Set up a table with the twelve months across the top. The left column will indicate crop information such as the following:
   1) Crop growth stages
   2) Insects (be specific)
      (a) If different insect stages affect the crop at different times, indicate what stage the insect is in and when it causes damage.
      (b) Indicate the period when insects are most likely to be present and when populations are most likely to cause economic damage
   3) Tillage operations
   4) Fertilizer applications
   5) Herbicide applications
   6) Harvesting

b) Now, look at the table (crop calendar) to see when each particular insect will most likely cause the most damage. Look at the growth stage of the crop at this time and think about the following questions.
   1) Is the insect attack happening at a critical time in the growth of the crop?
   2) Will the crop be able to grow out of any damage?
   3) Can the insect damage be prevented?
   4) What insect control measures can be used?
   5) What are the advantages and limitations of each of these methods?
   6) How much insect control is needed at this time, considering both the growth stage of the crop and the insect's life cycle?
   7) How will each of the methods affect the rest of the crop calendar?
   8) How much will it cost?
   9) When should the selected measures be started?
   10) What other factors should be considered in selecting a management plan?

F. Other activities

1. Talk to a local producer about what type of pest management plan he or she uses and how it was selected.

2. Look in a local pest management guide book and compare how the economic threshold, damage assessment, economic injury level, and cost-benefit analysis are determined for different crop and insect species.

G. Conclusion

An integrated pest management plan is an efficient and effective way to evaluate the needs and methods of pest control.

H. Competency

Outline an IPM plan.

I. Answers to Evaluation

1. d
2. b
3. b
4. c
5. a
6. d
7. a
8. c
9. c

NOTE: Part of the evaluation will be the completed IPM plan for the student's individual insect, WS 3.1.

UNIT - ENTOMOLOGY Name _____

Lesson 7: Integrated Pest Management Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is an IPM program?

   a. A program used to control insects instead of using chemicals
   b. A program used after insect damage has reduced crop yields
   c. An effective system used instead of an insect control program
   d. An efficient system used in developing an insect control program

2. What term describes the amount of damage insects do to a crop that equals the cost it requires to use measures that suppress the insects?

   a. Damage assessment
   b. Economic injury level
   c. Economic threshold
   d. Cost/benefit analysis

3. How is the economic threshold determined?

   a. By researching public records
   b. By careful sampling on a regular basis
   c. By calling a local extension office
   d. By monitoring costs and expenses

4. Which of the following steps is <u>not</u> a component of an IPM plan?

   a. Identify the problem
   b. Prepare cost/benefit analysis
   c. Get yield estimates from the local extension office
   d. Select a management strategy

5. What does "implementing a management strategy" mean?

   a. Actually putting a plan into action and seeing it through to completion
   b. The actual process of field cultivation
   c. Securing a loan from the bank for a plan
   d. Identifying the exact insects which can cause damage

6. Why is it essential to keep careful records of an IPM plan?

   a. Records are necessary when reporting costs for tax purposes.
   b. Records are necessary when reporting insecticide use to the EPA.
   c. Keeping careful records is not really essential.
   d. Records indicate how well a selected plan is working and how efficient and effective the measures are.

7. Why is a crop calendar used?

   a. It provides a systematic and efficient way of looking at the components in a cropping system.
   b. It provides a systematic and efficient way of selecting an insecticide.
   c. Provided by agricultural supply dealers, it indicates when agricultural practices should be done.
   d. It indicates what crops should be planted to reduce insect attack.

8. How is the information in a crop calendar used?

   a. Used to select the proper insecticide
   b. Used to select an appropriate crop to plant
   c. Used to evaluate potential problem and make a decision
   d. Used to determine how effective a crop rotation was

9. How are the "right" control methods selected?

   a. Methods are selected following recommendation calendars provided by local supply dealers.
   b. Correct control methods will fall below the cost-benefit analysis.
   c. There is no "right" or "wrong" choice in selecting control methods.
   d. Any control measure exceeding the economic threshold is considered wrong.

SINGLE NOZZLE HAND OR SMALL SPRAYERS

Method 1:

1. Mark off an area 10 feet by 10 feet.
2. Fill sprayer to a known mark and spray the area.
3. Refill the sprayer, measuring the amount of water required to refill to original level.
4. Determine the rate of spray delivery per acre for one nozzle:

Nozzle discharge per 100 square feet	**Amount of spray delivered per acre**
1/2 pint (1 cup)	27 gallons
1 pint	55 gallons
1 1/2 pint	82 gallons
1 quart	110 gallons

Applying 1 pint/100 square feet is equal to 1 gallon/800 square feet or 3 gallon/2400 square feet (24 feet x 100 feet).

Method 2:

1. Record the time while spraying 1 square rod (16 1/2 ft. x 16 1/2 ft.).
2. Catch the discharge from the nozzle in a bucket or other container for same period of time.
3. Measure the spray caught in pints.
4. Multiply the number of pints by 20. This equals the gallons per acre.

FIELD OR LARGE SPRAYER

Method 1:

1. Hang a container under each nozzle.
2. Operate the sprayer at the usual application pressure until about one pint of water has been collected in each of the containers.
3. Measure and record the output of each nozzle. Measurements can be made by the dip stick method, in ounces, cubic centimeters, etc.
4. Determine the total output collected from all the nozzles.
5. Determine the average by dividing the total output by the number of nozzles on the boom.
6. Multiply the average by 5 percent.
7. Subtract this figure from the average. This will be the low side of the 10 percent allowed.

8. Add this 5 percent figure to the average. This will be the high side of the 10 percent allowed.

9. The allowed 10 percent spread is between the low figure and the high figure.

10. Compare the output of each nozzle to these low and high figures.
    a. Take apart and clean all nozzles with an output below the low figure.
    b. Replace the nozzle with an output greater than the high figure with a new one.

11. After cleaning and replacing the nozzles, repeat steps 1 through 10. Frequently, the output of new nozzles varies greater than the allowed 10 percent.

The sprayer should be rechecked often, even after the original calibration. Be sure the same area is sprayed for each tankful as was planned in the calculation. If more or less area is sprayed than planned, stop spraying and recalibrate. This allows you to catch a small error in calculation or sprayer delivery rate before a major mistake is made. Equipment needs to be recalibrated whenever a different rate of application is used.

Method 2: Sprayer Calibration by the Ounce Method

Equipment needed:
100-foot tape
watch with a second hand
container graduated in **ounces** (liquid)

1. Select from the table below the appropriate distance based on:
    a) **Row spacing** is for a single nozzle or a group of nozzles directed at the row.
    b) **Nozzle spacing** is broadcast spraying over a non-row crop.
    c) **Band width** is band spraying. Measure off this distance in the field.

Row spacing, nozzle spacing, or band width (inches)	**Distance (feet)**
40	102
38	107
36	113
34	120
32	127
30	136
28	146
26	157
24	170
22	185
20	204
18	227
16	255
14	291
12	340
10	410
8	508

2. Drive the measured distance at the speed setting you desire to operate the sprayer. Accurately record the time in seconds.

3. Place the container graduated in ounces underneath one nozzle or nozzle group. Operate the spray in place at the selected pressure. Catch the discharge for the same amount of time, in seconds, as was recorded in Step 2.

4. The total discharge from the nozzle or nozzle groups, in ounces, has the same numerical value as the total gallons/acre (broadcast) applied by the sprayer.

5. To determine the number of acres that can be treated with a full sprayer tank, divide the total capacity of the sprayer tank by the gallons/acre value from step 4.

6. If **band spraying**, modify the gallons/acre (broadcast) from Step 4 and the insecticide rate (broadcast) with the following formulas.

$$\text{Gallons/acre} = \frac{\text{broadcast rate x band width}}{\text{row spacing}}$$

$$\text{Amount of insecticide needed per acre} = \frac{\text{broadcast rate x band width}}{\text{row spacing}}$$

7. Always recalibrate when the pressure, speed, and/or nozzles are changed.

APPLYING DUSTS AND GRANULAR FORMULATIONS

Before starting a dusting operation, the application equipment must be checked and calibrated. Even if the regulator on the equipment is at a given setting, the rate of application can change because different dust mixtures have different densities.

1. Read the operator's manual supplied by the manufacturer. Follow the instructions for adjusting equipment to the proper settings for the product and application rate being used.

2. Fill each hopper to an easily determined level or mark.

3. Measure off an area at least 1/4 acre or 1,000 feet of row. Example: Eight 40-inch rows 1/4 mile long equals 0.808 acres.

4. Dust the measured area. Drive at a constant speed and use a speedometer if possible. The speed affects the application rate. A constant speed is necessary to apply the insecticide evenly and accurately.

5. Refill the hopper to the same level. Carefully weigh the amount of insecticide needed to refill the hopper. Another way to do this is to weigh accurately a given amount of the dust product. Refill the hopper with this dust. Weigh the amount of dust leftover. Subtracting the second weight from the first weight will give the amount of dust needed to refill the hopper.

6. The amount of insecticide dust it takes to refill the hopper is the amount applied to the measured area or distance.

7. Determine the application rate by dividing the amount applied by the area.

   Example: Suppose a bag contains 50 pounds of dust product. This was used to refill the hopper. After refilling the hopper, the bag weighed 34 pounds. Sixteen pounds were applied (50 pounds - 34 pounds = 16 pounds). Dividing 16 pounds by 0.808 acres gives 19.8 pounds per acre.

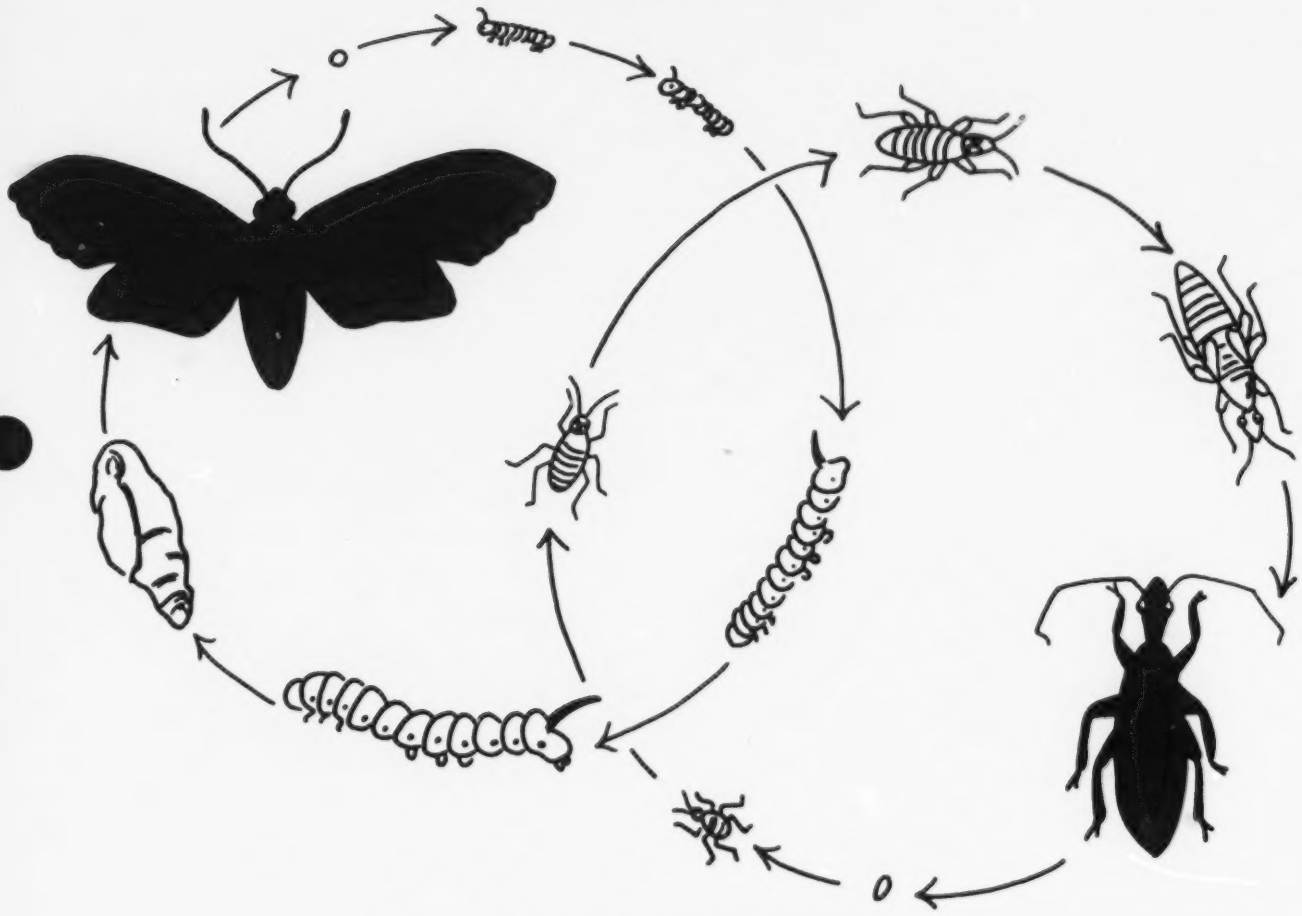
8. If the amount applied does not fall within 5 percent of the recommended dosage, reset the gate openings and repeat the previous three steps.

9. Keep a record of the acreage treated with each filling of the hopper. This will let you see any slight change in rate of application and make the necessary adjustments.

MISSOURI AGRICULTURAL EDUCATION

Entomology

for Agricultural Science II
Core Curriculum



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FOREWORD

This reference, Entomology, is designed to accompany the lessons outlined in the instructor's guide in the Agricultural Science II Core Curriculum. The development of this guide is the result of suggestions by the MVATA Teaching Aids Committee. The Entomology Advisory Committee suggested the topics to be discussed and reviewed the materials.

This unit is a basic introduction to the world of entomology. Seven lessons have been developed: Introduction to Entomology, Insect Collection, Insect Identification, Methods of Control, Chemical Control Methods, Safe Use of Insecticides, and Integrated Pest Management. Persons using this reference on an individual basis may wish to secure a copy of the instructor's guide for additional materials on entomology.

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ENTOMOLOGY

TABLE OF CONTENTS

ACKNOWLEDGMENTS ii

FOREWORD iii

Lesson 1--Introduction to Entomology 1
- Entomology
- Uses of Insects
- Careers in Entomology
- Career Areas Enhanced by Entomology

Lesson 2--Insect Collection 5
- Collecting Insects
- Preserving Insects
- Labeling
- Pinning
- Spreading Butterflies and Moths
- Collection Arrangement and Care

Lesson 3--Insect Identification 13
- Distinguishing Characteristics of an Insect
- The Three Main Sections of an Insect
- Life Stages of Insects
- Insect Classification
- The Insect Orders

Lesson 4--Methods of Control 21
- Control Methods
- Biological Control
- Cultural Control
- Physical and Mechanical Control
- Chemical Control

Lesson 5--Chemical Control Methods 25
- Pesticides
- When is an insect considered a pest?
- Pesticide Types
- Mode of Action
- Methods of Insecticide Application
- Insecticide Formulations
- Applying Insecticides
- Sprayer Calibration

Lesson 6--Safe Use of Insecticides 31
- The Insecticide Label
- Insecticide Toxicity
- Pesticide Certification
- Safety Guidelines for Using Insecticides
- Disposal of Insecticides and Insecticide Containers
- Symptoms of Insecticide Poisoning
- First Aid Procedures for Insecticide Poisoning
- First Aid Kit
- Poison Control Center

Lesson 7--Integrated Pest Management 37
IPM
Why IPM is Important
Economic Threshold
Steps in an IPM Plan
Crop Calendars

Glossary 41

What is an insect? An insect is any kind of bug. Well, no, that is not a very descriptive or clear definition. An insect can be defined simply as a small, six-legged animal. Of the million kinds of animals that scientists have described and named, more than 800,000 are insects. Around 7,000 to 10,000 new kinds of insects are discovered every year. Insects live almost everywhere on earth - from steamy tropical jungles to cold polar regions, from snow-capped mountains to deserts below sea level.

Entomology

The study of insects is called **entomology**. The study of insects includes their development, anatomy, physiology, life history, behavior, environment, and classification. Why should we spend time studying insects? Why is entomology important to us? Although some people may think that the study of insects is a small, isolated field, entomology is important to all of us because of the wide range of influence insects have in our lives. Their effect is both direct and indirect, both positive and negative. Entomology gives people a better understanding of the environment, biology, and the world in which they live. An understanding of entomology is also needed to reduce the extensive economic losses in crop damage and health problems caused by insects.

Uses of Insects

Agriculture - In agriculture, insects are considered harmful and beneficial. Agriculture includes any field involved in growing crops for food and fiber, horticulture (fruits, flowers and ornamental plants), forestry (managing forests, wood production and wood products), and animal science (raising and caring for animals whether as pets or for food production). Insects are one of the chief competitors for food and fiber. Each year insects cause millions of dollars in damage to field crops, vegetables, fruits, and fibers in all stages of growth, production, storage, processing, and distribution.

Insects are not just pests to our society. Many are beneficial to humans. Insects are an important part of the food chain. Birds and fish eat insects directly to survive. Many mammals and reptiles feed on insects as well. The indirect contribution can be seen in the work of bees. Not only do bees make honey, but they also play an important role in pollinating plants. Some insects are helpful to humans by preying on and destroying other insects that are considered harmful. Another example of useful insects is the silkworm, which makes a valuable fiber for clothing and other items.

Environmental sciences - Besides their role in the agricultural fields, insects are very active in breaking down many of the substances in the environment. Many kinds of chemicals, minerals, and organic matter are broken down, recycled, and reused in the environment. Insects play an instrumental part in this degradation process, which is very important to the earth.

Medicine - Insects can transmit diseases by many methods. Insects are a very important part of the research to find out about diseases. This includes animal and plant diseases as well as human diseases.

Because insects reproduce so efficiently and can be handled so easily in large populations, they have been used extensively in genetic research. This contribution to science has provided researchers with a great wealth of knowledge about heredity, biological growth and development, and the causes and treatments of diseases.

Construction - Another large area of insect management is in building construction and maintenance. A knowledge of entomology is important when choosing the type of wood to be used in buildings and other structures. Termites cause much damage to wooden structures and building framing. Soil insects are an important consideration when constructing building foundations, roads, structural supports, and landscaping.

Product development - Insects are used in the research and development of many products used in society. Some of the most common products are cosmetics, shampoos, cleaning materials, food preservatives, manufacturing supplies, and medicines.

Careers in Entomology

Scientists devote much study to insects that affect plants or animals which are important to man. Scientists who specialize in studying insects are called **entomologists**. Entomologists are involved in a wide variety of professions, both directly and indirectly. Some careers require an extensive knowledge of entomology while other careers only require a general knowledge of insects. Many of these career areas overlap one another. One specialty may be used in many different ways in many different fields.

Entomologists can be grouped by their area of insect study. Most professional entomologists are engaged in some branch of **economic** or **applied** entomology. This is a very broad category that describes the basic focus of these individuals. They not only want to control the numbers of insects, but to increase those insect populations that are beneficial and to decrease those that are harmful to people's welfare. Economic and applied entomologists use the study of insects in a practical way. Other entomologists study insects solely to learn more about their life cycles and behaviors.

Agricultural entomologists - Agricultural entomologists study insects that affect the production of foods and fibers. These individuals work in areas of agriculture such as agronomy, animal science, horticulture, floriculture, forestry, and wood processing. Some of the careers as an agricultural entomologist follow.

1. Crop scout - Scouts monitor crop fields and take samples of the types and quantities of insects present. This is important in determining the amount of potential damage which may be done by the insects. From this information, a producer is better able to select an appropriate insect management plan. Usually, attending a training program is the minimum requirements for a scout. However, experience and education in entomology will enhance an opportunity for a better job in scouting.

2. Agricultural product dealer - Any background at all in entomology will help one as a product dealer. Dealers must keep up with a wide variety of agricultural products and how they work. Since insect control is a major concern for producers, dealers are frequently asked for their suggestions and recommendations in selecting the products to be used.

3. Pest controller - Individuals have a large selection of jobs as pest controllers. Pest controllers evaluate insect populations and damage, recommend insect management programs, implement these programs, apply insecticides, and dispose of any chemicals. Home care, industrial insect management, and termite control are leading employers in this area. Depending on the particular job responsibilities, individuals may need little or much formal education. Certain types of insecticides require special certification.

4. Insecticide applicator - Insecticide applicators are responsible for the correct application and disposal of insecticides. This includes applications on the ground or by air, privately or commercially, and on domestic or public grounds. Usually, the applicator needs to attend a special training course to be certified.

5. Researcher - There are many options in research involving insects. Most university and industrial research positions require a doctoral degree. To be a research assistant, a laboratory technician, or field technician, individuals may need a master's degree, a bachelor's degree, or less depending on the place of employment and the responsibilities of the position. Consultants may have any level of education, although a graduate degree is frequently required.

6. Forester - Forest entomologists specialize in studying insects that affect different woods and how to properly treat these woods. A bachelor's degree is usually necessary.

7. Greenhouse manager - Working in a greenhouse or any similar environment involves insect control. Some fruits and vegetables as well as flowers are grown and shipped to all parts of the country. A bachelor's degree or higher is standard at this management level. Technicians and assistants may be hired with less qualifications.

Entomology instructors - Individuals may teach entomology at elementary, secondary and postsecondary levels. An individual can be an educator in many areas of specialization. Different training levels are required depending on the educational setting and student level. A doctoral degree is frequently needed to teach in a university. High school and vocational teachers need a bachelor's degree. Some states require that high school teachers be certified in pesticide application as well.

Medical and veterinary entomologists - These entomologists are concerned with insects that influence the health of humans and of animals. It is largely through the efforts of these scientists that insecticides have been developed to protect crops and to reduce the incidence of insect-borne diseases. Jobs in this area generally require a graduate degree in the area of medical specialization. The degree may or may not be in entomology, but extensive college training in entomology is necessary. It is possible to become a research assistant, laboratory technician, or teaching assistant with a bachelor's degree or perhaps even a two-year degree. There are a variety of choices and flexibility in this area.

Industrial entomologists - Individuals work in the research and manufacture of many types of products for industrial and domestic use. There are some jobs available for individuals with a high school diploma and some technical training. Many other jobs will require additional training. A knowledge of insects is useful in the testing and development of products. Examples of products are cosmetics, shampoos, cleaning materials, food products, industrial supplies, medicines, and insecticides. Many products contain insecticides as a preservative or as part of the chemical formulation.

Ecological entomologists - These entomologists are concerned with making regulations and enforcing the standards for protecting the environment, public health, and safety. Proper waste disposal and treatment are also included. Usually a bachelor's degree or higher is necessary.

Career Areas Enhanced by Entomology

There are many careers that do not require a professional degree in entomology, but they are enhanced by a general or working knowledge about insects. The job will determine how much knowledge about insects is required. Some occupations may require special licensing, such as in pesticide application. Occupations that benefit from a working knowledge of entomology include landscaping and turf management, animal and human medical care, food science, and biological science.

Landscaping and turf management - This area involves the care and maintenance of landscaped areas. People in this area take care of lawns and ornamental plants at domestic homes, public grounds, parks, golf courses, etc. Generally, a bachelor's degree or higher is required to be a supervisor. Less education is needed to be a technician or assistant. The job requirements will vary greatly depending on the size of the operation and the responsibilities one has. The area of pest control greatly overlaps here. Workers may need to have a pesticide certification if they apply certain insecticides.

Animal and human medical care - Areas of animal and human health care enhanced by a working knowledge of insects include medical assistants, research assistants, field technicians, horse groomers, livestock workers, and pet shop workers.

Food science - This is a large area involving any aspect of handling food. This includes processing, preservation, storage, packaging, transportation, and distribution of food for people or animals. People involved in food science also work in the development of new foods and serving methods. They work in restaurants or cafeterias and as dieticians. Some individuals work with agencies concerned with the regulation and enforcement of food quality and health and safety standards.

Biological science - This area includes all aspects of agricultural, ecological, and environmental sciences. For example, a conservationist needs to understand how changes in the environment affect insect populations.

Summary

Entomology is the study of insects. Entomologists study the development, anatomy, physiology, life history, behavior, environment, and classification of insects. The impact of insects on society is enormous. There are many fields that employ entomologists and many others that are enhanced by a working knowledge of insects.

Credits

Apply Pesticides Correctly. Washington, DC: United States Department of Agriculture. U.S. Government Printing Office, 1975.

Bland, R.G. How to Know the Insects. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Borror, D.J. and R.E. White. A Field Guide to the Insects. Boston, MA: Houghton Mifflin Company, 1970.

Boyd, E.M. Toxicity of Pure Foods. Cleveland: CRC Press, 1973.

Evans, Howard E. INSECT BIOLOGY: A Textbook of Entomology. Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

Greenhouse Operation and Management. University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

Guidelines for Insecticide Use. Lexington, KY: University of Kentucky, Department of Entomology, 1989.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington DC: United States Department of Agriculture. U.S. Government Printing Office, 1982.

Insect Control Recommendations. University of Missouri-Columbia: University Extension, 1990.

Pest Management Strategies in Crop Protection. Washington, DC: Congress of the United States. Office of Technology Assessment.

The Random House Encyclopedia. New York, NY: Random House, Inc., 1977.

Making an insect collection is an ideal way to learn about insects. It opens the doors to the world in which these small creatures live. The collector is able to discover things about insects that he or she may not get from books. It allows insects which are very different to be studied and compared at the same time. Collecting insects is a very interesting hobby as well. Constructing an insect collection is not difficult, but it does require some care and time. There are certain steps and procedures that need to be followed when preparing insects for display. Some standard guidelines are given here.

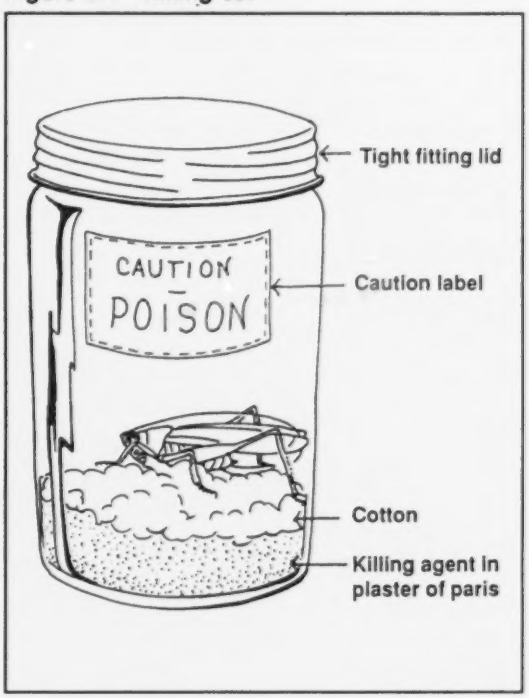
Collecting Insects

Preparing a killing jar - A killing jar needs to be prepared before the insects are collected. Insects should be killed in a killing jar as soon as possible after they are collected. Therefore, the killing jar should be taken along when collecting insects. Killing jars or bottles can either be made or purchased. Wide-mouth jars (6 to 16 oz. size) with airtight lids are the most common. An alternative is to carry a large test tube or slender bottle with a cork or stopper in it. The insects are killed later.

Ethyl acetate, which acts as a fumigant, can be used to make a killing jar. It can be obtained from biological or chemical supply companies. It is much safer than other types of killing agents. The ethyl acetate type of killing jar can be made easily by following the procedure listed below. See Figure 2.1.

1. Make a thick mixture of plaster of paris and water.
2. Pour the mixture into a clean jar to a height of about 1 inch (20-30 millimeters). Allow it to air dry at room temperature (this requires several days) or under low heat (light bulb or lowest oven temperature).
3. When completely dry, add enough ethyl acetate to saturate the plaster of paris. With the lid on, let it stand for a few minutes. Then, pour back any excess liquid and replace the lid. There should not be any standing liquid. Be careful not to breath the ethyl acetate fumes.
4. Place enough cotton to cover the plaster of paris. The insect should not come into direct contact with the plaster of paris.
5. Tape can be placed on the bottom and lower sides of the jar to reduce the chance of breakage.
6. Label the jar "poison."
7. Ethyl acetate must be reapplied to the plaster of paris after several hours of collecting insects depending on how often and for how long the lid was removed. The lid should always be left on unless the collector is actually placing an insect in or removing one from the jar.

Figure 2.1 - Killing Jar



Locating insects - Insects can be found almost anywhere in the world. The more places you look, the more kinds of insects you are likely to find. Insects are commonly found in flower and vegetable gardens, grasses in lawns and fields, weeds, bushes, aquatic plants, fruit and shade trees, and animals.

Many insects can be found hiding in plants. Look between the petals in flowers and inside the stem. Leaf damage may indicate the presence of insects. If the stem has holes, swellings, or a dead portion, it should be split to locate larvae living there. Soil insects, which feed on roots, are often found near or inside roots. Decaying fruits, nuts, vegetables, bark, logs, and wood piles are homes of many insects. Check tree holes that are filled with water for mosquito larvae and other insects.

Flying insects enjoy sunny, calm days. Certain flies, winged ants, and termites swarm in the spring and fall, especially when it is warm and sunny after rain. Use a net to catch flying insects, or check the radiator or front grill of a car for usable specimens. Certain insects may be found beneath or on top of the water. Mud along water shorelines is also the hiding place for many insects. Like plants on land, water plants are also homes for several kinds of insects.

A lot of insects may be hiding in garden topsoil, mulch, compost piles, and forest litter. To find certain soil insects, dig down about six inches under grasses and in garden soil. Since insects are almost everywhere, there are many other places to find them. Outside areas like under stones, logs, plant debris, and picnic trash bins are homes of insects. Household pests may be found in garages, basements, and food storage areas. Parasitic insects live in bird feathers and animal skin and fur. Some insects are not present during the day, but may be found at night.

Catching insects - The simplest way to catch insects is by hand. Place them in a killing jar or container. Gloves are recommended for catching insects. Many beginners may be hesitant to reach out and grab an insect because they are afraid that it might bite or sting. Although this is a common fear, it is not very likely to occur with most insects. Insects which bite do so by moving their jaws sideways and pinching, or by piercing with their beak. Actually, there are very few pinching insects capable of causing pain or breaking skin. Most biting insects can not bite if they are grasped firmly by the sides of their body. Insects which sting do this by using a structure located at the back end of their body. Only female bees, wasps, and some ants can sting.

A net, envelopes, small boxes, forceps, a hand lens, flash lights, and killing jars are useful when gathering insects. A net is used by swinging it at insects as they go by or swinging it through vegetation or along the surface of water. To prevent the insect from escaping, quickly turn the net handle so that the bag folds over the rim. Insects should be removed from the net as gently and carefully as possible to prevent damage. To remove insects from the net, you can 1) remove them directly by gently grasping them with fingers or a tool, 2) insert a box or bottle into the net and ease the insect into this container, or 3) work the insect into a fold in the net and place this fold into a killing jar to stun the insect directly. If the insect is one that stings, it can be worked into a fold in the net and stunned by pinching the thorax before removal.

Killing insects - Place insects immediately into the killing jar after they are captured. If the killing jar is in use, the insects can be placed into another container with a lid. It is important to kill the insects as soon as possible so that they do not damage their body parts.

Preserving Insects

Specimens are kept in killing jars until it is time to preserve them. Most insects are normally preserved by "pinning." Pinning is a way to mount and preserve insects indefinitely. Insects should be pinned immediately after they are killed. Otherwise, they become very brittle after drying and can easily break if mounted later. Soft-bodied insects, larvae, and nymphs need to be preserved in liquid. The bodies of these insects will shrivel when dried. The most common liquid used for killing and preserving these insects is an alcohol solution.

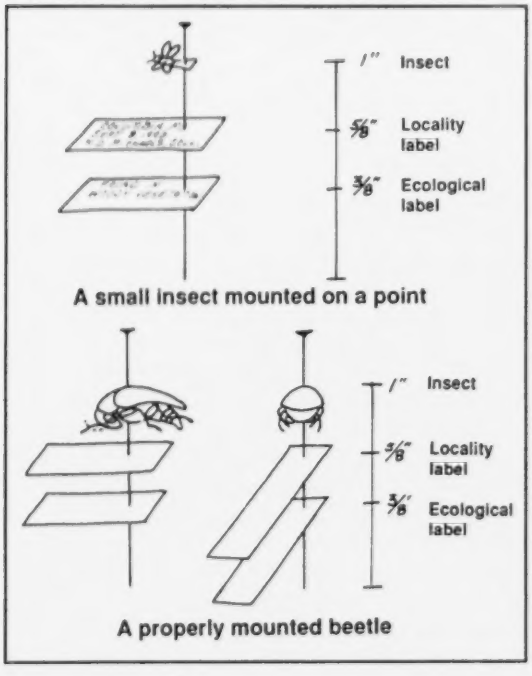
Another method for preserving insects is to keep them in envelopes. This works best for insects that have relatively slender and fragile bodies, such as dragonflies, damselflies, and crane flies. Using envelopes saves a lot of space and protects these types of insects better than mounting on pins. Envelopes can be made of paper or plastic. Label information is either written on the outside of the envelope or written on a piece of paper and placed inside the envelope.

Labeling

Locality and ecological labels - Labeling is a very important part of an insect collection. The information should be accurate and written clearly. Without data a specimen is useless. The first label, which is the locality label, must include the date when the insect was found and the place where it was caught. It may include the collector's name. A second label, called the ecological label, may be used. The ecological label would contain information or observations about the insect's environment or habitat.

These labels are made of fairly stiff white paper. They are about 1/4 by 3/4 inches or smaller in size. The labels are mounted on the pin at the proper heights and parallel with the insect (or point). The insects and labels could be mounted using a pinning block at the following marks: insects at the 1-inch mark, locality labels at the 5/8-inch mark, and ecological labels at the 3/8-inch mark. See Figure 2.2. They can be mounted so that they are read from either the right or left. Just make sure that all labels are read from the same direction. This helps keep the collection neat and orderly. For specimens mounted on microscope slides, the information is written on a slide label.

Figure 2.2 - Insect and Label Placement



Identification labels - An insect collection should contain some identification labels. Specimens in a collection should be arranged into groups according to insect orders. One label is used to identify each group. If the insects are labeled to the scientific level of species, an identification label is used for each individual specimen. A piece of paper about an inch square is used for the identification label. This is placed alongside a group of insects or at the base of the pin for individual insects. These types of labels contain the order of the group of insects or the scientific name of the insect, the name of the person identifying it, and the month and year when the identification was made.

Pinning

A special system has been developed for pinning insects. The procedures should be followed as closely as possible. Pinning is done with special **insect pins**, pins which are made especially for this purpose. They are sold in several sizes. The most common are Number 1 (very thin), Number 2 (thin), and Number 3 (thick, for larger insects). The simplest way to handle an insect for pinning is to hold the insect between the thumb and forefinger of one hand and insert the pin with the other hand.

Different insect types are pinned in different places. See Figure 2.3. Most insects are pinned through the thorax vertically. Beetles and hoppers are pinned through the front part of the right wing. Make sure the pin does not damage a leg as is comes through on the underside of the body. True bugs are pinned through the scutellum, if they are large enough. The scutellum is the triangular area between the bases of the wings. Otherwise, they are pinned like beetles through the right wing. Grasshoppers and crickets are pinned through the thorax between the bases of the front wings and just to the right of the midline.

Dragonflies and damselflies can be pinned in two ways. The best way is to pin them sideways. The left side should face up with the wings together above the body. The pin goes through the thorax below the wing bases. If the wings are

not together when the insect is removed from the killing jar, place the specimen in an envelope with the wings together above the body for a day or two. The specimen is ready to pin when it has dried enough for the wings to stay in position. The other way is to pin the insect through the thorax with the wings placed horizontally.

Figure 2.3 - Pinning Locations

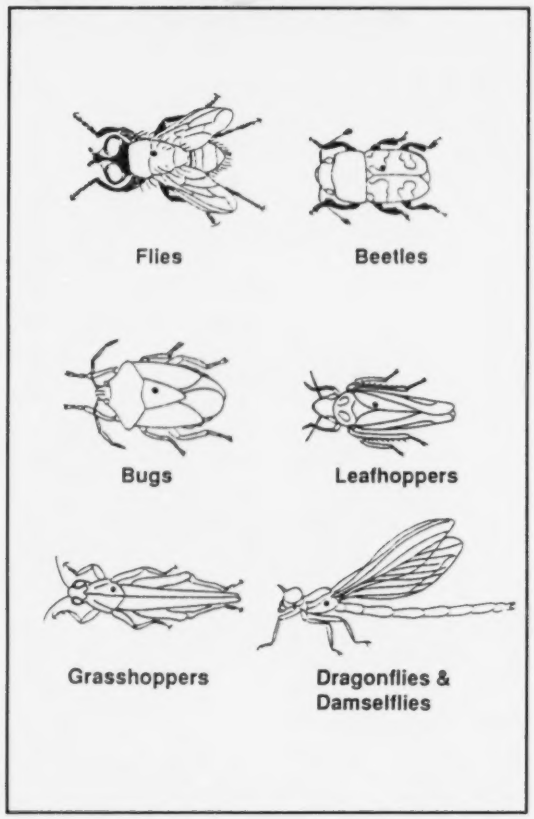
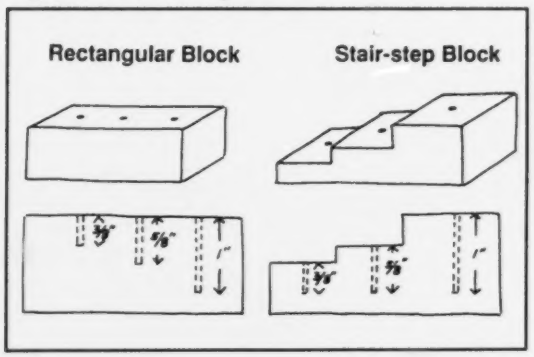


Figure 2.4 - Pinning Blocks



When mounted, all of the insects and labels on pins should be at the same height. The easiest way to do this is to use a pinning block. See Figure 2.4. A pinning block is usually made of wood. The block can be shaped as a solid rectangle or like stair steps. Holes are drilled to 1, 5/8, and 3/8 inches in depth. The following procedure should be followed when using a pinning block.

1. After placing a specimen on a pin, insert the pin in the 1-inch hole.
2. Then, add the first label and insert the pin in the 5/8-inch hole.
3. Finally, add the second label, if there is one, and insert the pin in the 3/8-inch hole.

A mounted insect with two labels should look like Figure 2.2. Pinned specimens can be temporarily stored on a sheet of cork, balsa wood, or other soft material until placement into the collection.

The abdomen of some insects, such as dragonflies, may sag when pinned. One of the following techniques can be used to prevent this. The insects should be allowed to dry completely before they are placed in the collection.

1. Stick the pinned insect onto a vertical surface with the abdomen hanging down.

2. Place a small piece of cardboard on the pin just under the insect so that the abdomen is supported.
3. Insert two pins so that they cross under the abdomen. They will support the sagging abdomen.

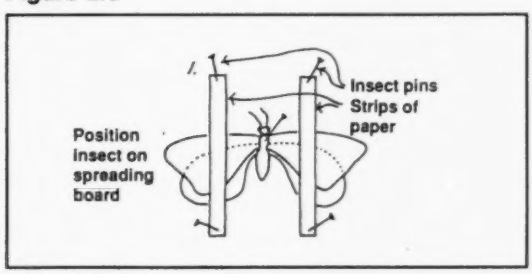
Some insects may be too small to put a pin through. These are usually mounted on a small triangular piece of cardboard called a **point**. Points are about 3/8 inch (8 millimeters) long and 3/16 inch (3-4 millimeters) wide at the base. The insect is glued to the tip of the triangle and the pin is put through the wide base. The entire set-up is then mounted on the block as described before. Be careful to glue the insect so that the body parts you want to examine are not hidden. The suggested way is to glue the insect on the right side with the head facing away from the pin. A household cement or glue should be used.

Spreading Butterflies and Moths

For most insects, the exact position of the legs and wings is not generally important as long as all of the body parts can be seen. Insects such as butterflies and moths need to have their wings spread before being put into the collection. Insects can be spread on a spreading board or on a flat surface. To "spread" an insect on a spreading broad follow the steps below. If a spreading board is not available, spread the specimen upside-down on a flat surface.

Step 1 - Hold the specimen by grasping it by the thorax, the middle section of an insect. Holding it right side up, insert a pin through the middle of the thorax. Move it to the 1-inch position on the pin. The pinned specimen is then lowered onto the spreading board. The pin should go into, and maybe even through, the bottom of the groove. Push the pin through the board until the underside of the wings is even with the top piece of the spreading board. Pin narrow strips of paper over the wings on each side as indicated in Figure 2.5.

Figure 2.5

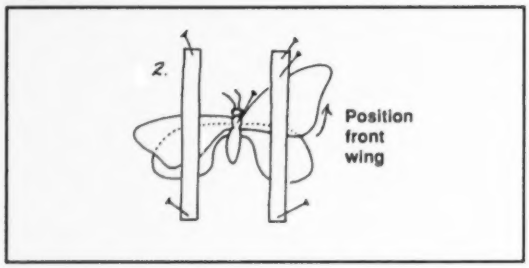


Step 2 - Remove the pin on one side at the lower end of the strip of paper. Raise the front wing until the rear edge is at a right angle to the body. See Figure 2.6. Forceps, a pin, or some other tool may be helpful in doing this. Be careful not to tear or puncture the wing. When the wing is in place, insert a pin through the strip of paper just in front of the tip of the wing. Pin the lower edge of the paper strip back into place.

Step 3 - Repeat this procedure with the other front wing.

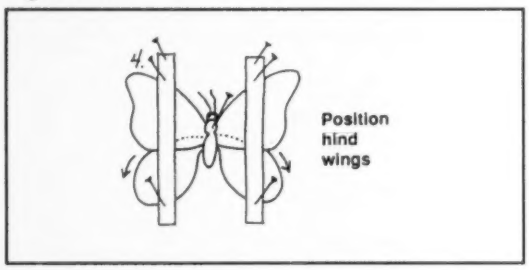
Step 4 - Using forceps, a pin, or some other tool to raise the hind wing on one side until the space between the two wings is reduced, as shown. The

Figure 2.6



front and hind wings of these insects will overlap at the base with the front edge of the hind wing under the rear edge of the front wing. See Figure 2.7. Move the pin in the lower part of paper strip until it is just below the tip of the hind wing.

Figure 2.7

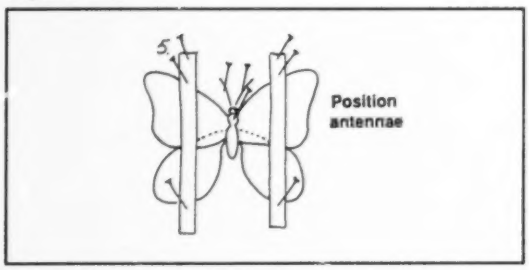


Step 5 - Repeat this procedure with the hind wing on the other side.

Step 6 - Now, position the antennae so that they appear balanced. Put pins alongside of the antennae to hold them in place. See Figure 2.8.

Step 7 - Fasten the legs close to the body at right angles to the body. This is done by placing a strip of paper across the entire body.

Figure 2.8



After spreading the wings, the insect is left in position until it dries. How long it takes the insect to dry completely depends on the size of the insect, the temperature and humidity. A large butterfly may take several days at room temperature or an hour with heat. Ovens or electric lamps are used as sources of heat. A specimen is dry when the abdomen is stiff when gently touched with a pin. If the abdomen is still flexible, the insect is not dry enough.

Collection Arrangement and Care

Once the insects are collected, preserved, pinned, and labeled, they need to be kept in an orderly and safe way. There is no exact way to organize an insect collection. The way the insects are arranged will depend on the size of the collection, the types of insects collected, and the preference of the individual. Whatever way it is done, the collection should be neat and orderly, and the insects easily seen. Specimens are kept in some sort of display for study and storage. There are several different kinds of mounting displays. These mounting containers can be bought at a local supply store or handmade.

Mounting box - The most common type of display for pinned insects is a mounting box. The box is made of wood or heavy cardboard. Boxes can be any size but usually measure about 9 x 12 x 3 inches and have a tight-fitting lid. The bottom is lined with a material that is sturdy enough to securely support the pins but soft enough to easily insert the pins. These materials are usually sheet cork, balsa wood, Styrofoam, or corrugated cardboard.

Riker mounting - The Riker mount is a second type. This is a box with one piece of glass on the top. The box is filled with cotton and the insects are mounted on the cotton just under the glass. A small depression is made in the cotton before putting in a thick-bodied insect. Insects in a Riker mount can be seen easily and the mounts handled without damaging the samples. However, only one side of the specimen can be seen. Also, some insects, such as moths, tend to fade after a lot of exposure to the light.

Glass mount - The glass mount is another kind of display. This type has two pieces of glass, one on the top side and one on the bottom side of the box. The size and the materials used for glass mounts are similar to Riker mounts. Glass mounts contain no cotton. This makes it possible to see both sides of an insect specimen. Each glass mount contains only a few insects. They are relatively inexpensive and provide a safe, attractive method for storing and displaying insects.

Plastic mount - Plastic mounts are made of two sheets of thick plastic. The insect is mounted between the plastic. Then, the edges are sealed with acetone or tape. An alternative type of plastic mount is made by embedding an insect in a block of plastic. This is a very involved process, but the end product is very attractive, durable, and permanent.

Slide mount - Insects or parts of insects can be studied in detail by mounting them on slides. Small insects, insects that shrivel-up when dried, and soft bodied insects are commonly mounted on slides. Also parts of insects such as the wings, mouth parts, genitalia, legs, and antennae are mounted on slides for further study. Some specimens have areas that are dark colored. Usually these areas are treated before mounting. The treatment removes some of the dark coloring so that it can be seen better. Samples are mounted on microscope slides using different chemicals. These chemicals have different functions. More information on the purposes of these chemicals can be found in technical books on the subject.

Insect collections need to be protected from beetles and other pests that can attack and damage the specimens. Collections should be examined regularly for signs of damage. Special pest repellents can be bought to treat collections. For a box display, the repellent can be placed in a small pillbox or wrapped in a piece of cloth. It is then placed securely in one corner of the box. For Riker mounts, the repellent can be placed underneath the cotton. Specimens sealed in glass mounts or in plastic need to be treated with repellent before the mount is sealed.

Insect specimens are very brittle when they are dry. They always need to be handled with care. Otherwise, the legs, antennae, wings, and other parts may be broken off. However, if parts do get broken off, use glue or cement to replace them.

Summary

Making an insect collection is an ideal way to learn about insects. It allows insects that are very different to be studied and compared at the same time. Constructing an insect collection involves making a killing jar and locating, preserving, pinning, mounting, labeling, and arranging the insects. The proper techniques should always be followed when making an insect collection. When properly done, a collection can last a very long time. An insect collection is a great adventure into the world of insects.

Credits

Bland, R.G. How to Know the Insects. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Borror, D.J. and R.E. White. A Field Guide to the Insects. Boston, MA: Houghton Mifflin Company, 1970.

Evans, Howard E. INSECT BIOLOGY: A Textbook of Entomology. Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

The Random House Encyclopedia. New York, NY: Random House, Inc., 1977.

Lesson 2 presented information on where to look for insects, how to collect them, and how to prepare specimens for a collection. The next step is to learn the details of insects' bodies, the distinguishing features of each order, and how insects are divided into groups.

Distinguishing Characteristics of an Insect

What exactly is an insect? In Lesson 1, an insect was defined as a small six-legged animal. In this lesson, an insect will be more clearly defined. What determines which animals are put into this class and which are not? There are certain characteristics which set insects apart from other animals. An insect is a small animal without a backbone that has the following external characteristics as an adult:

1. A hardened external skeleton
2. Three distinct body regions: head, thorax, and abdomen
3. One pair of segmented antennae
4. Three pairs of segmented legs on the thorax segment
5. One pair of compound eyes (Some insects have no eyes.)
6. One or two pairs of wings (Some adults are wingless.)

Before becoming adults, insects are called **immatures**. The shape of immatures depends on the species. The best way to study and identify insects is to look at the three main body sections: **the head, thorax, and abdomen**. See Figure 3.1.

The Three Main Sections of an Insect

Head - The head is the hardened region at the front of the body, which includes the eyes, antennae, and mouth parts. There are two types of eyes. Simple eyes are small eyes located on top of the head in adults. Compound eyes are the large eyes found on most adult insects. These eyes contain a few to several thousands individual eye units. Often insects can only see light and dark areas and cannot see objects distinctly.

Insects have one pair of antennae. Antennae are two long, jointed feelers that grow from the insect's head. Antennae are flexible and come in a variety of shapes. See Figure 3.2. Antennae

Figure 3.2 - Types of Antennae

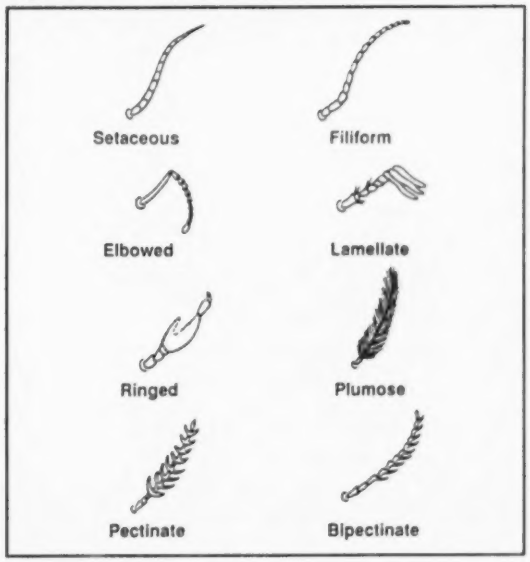
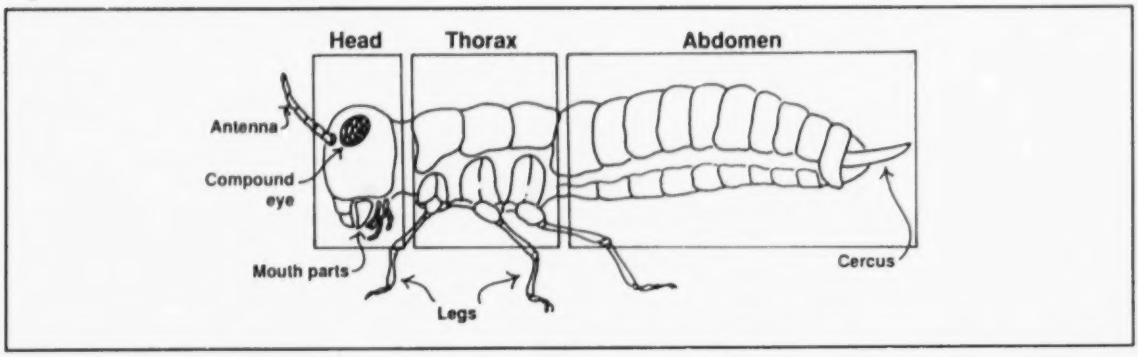
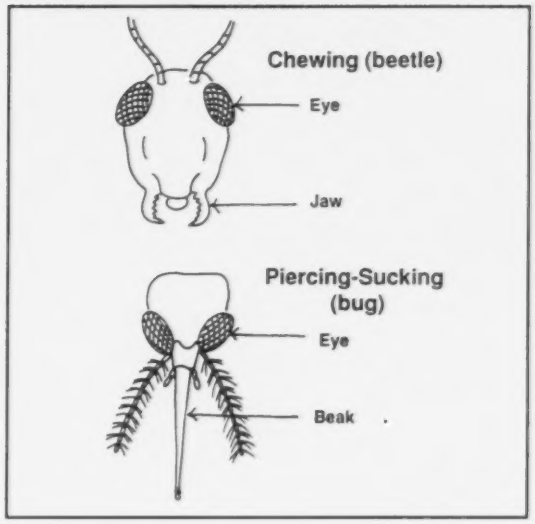


Figure 3.1 - Three Main Sections



function as sensors to detect the odor, sound, taste, and feel of the surrounding environment. The mouth parts are also in the head region. Chewing and piercing-sucking are the two main types of mouth parts (Figure 3.3). Some insects will have a modification or adaptation of these. Mouth parts determine how the insect feeds. Chewing mouth parts are strong, curbed, and toothed. They are used for chewing, cutting, crushing, or grinding. Chewing mouth parts crush hard seeds and tear food into pieces. Mouth parts may have other functions as well. Chewing jaws can be used like scissors or tongs. They can also dig like little shovels or plow like tiny bulldozers. Some insects use their strong jaws to squeeze their enemies to death or to cut off their heads.

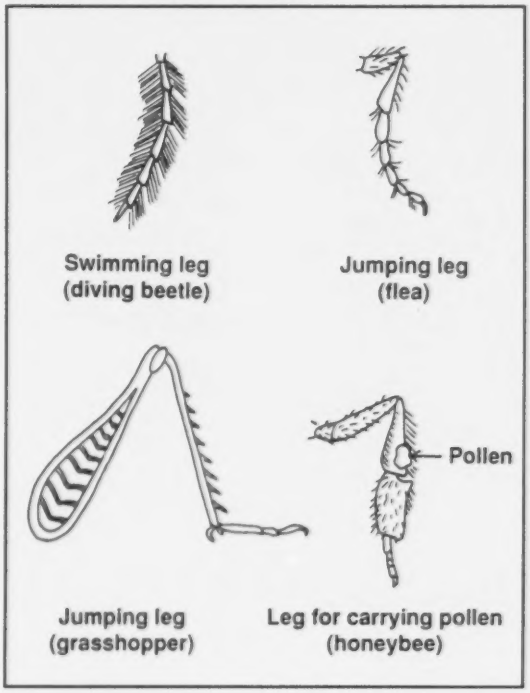
Figure 3.3 - Mouth Parts



Piercing-sucking mouth parts are long and needle-like for piercing leaf surfaces or skin. Special sucking structures suck up the fluids. Examples of mouth parts that are a variation of chewing and piercing-sucking are rasping-lapping, reduced chewing, chewing-sucking, and sponging. How these are used depends on the particular insect species.

Thorax - The thorax is the second section of an insect's body. This section contains the nerve centers and muscles that control the insect's movement. Wings and legs are attached to the thorax. Insects have three pairs of legs. Each leg has five parts, although sometimes the parts are hard to see. The legs come in many forms depending on their functions, such as running, jumping, grasping, or swimming. See Figure 3.4.

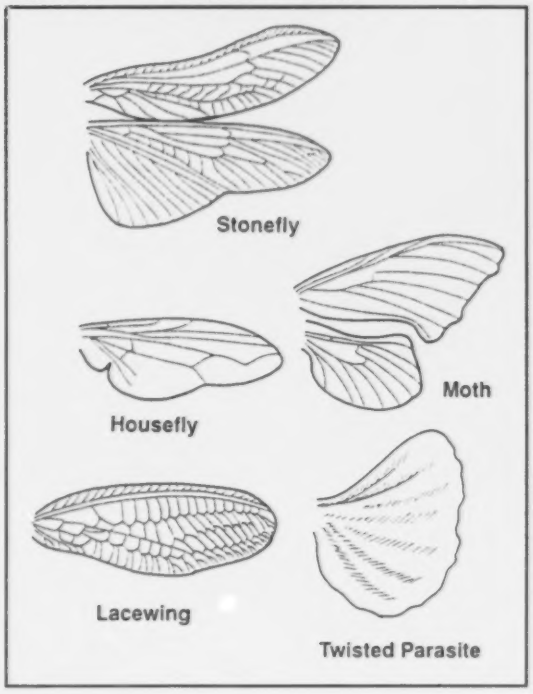
Figure 3.4 - Types of Legs



Adult insects may not have wings. There is a great variety in the shape, size, color, thickness, and vein pattern of insect wings. See Figure 3.5. The shape of the wings and the pattern of the veins is used widely in identification.

Abdomen - The abdomen is the third section of an insect's body. It may be visible or hidden underneath the wings. This section contains the internal organs of the insect. It is the location of the stomach and intestines, where food is digested and absorbed. There is also a place that is used to store food and to carry it back to the nest for other insects. The sexual organs are in the abdomen as well. The abdomen has glands that secrete different types of fluids, such as liquids that mark their trails or drive enemies away. This section may also have a needle-like projection for piercing or stinging.

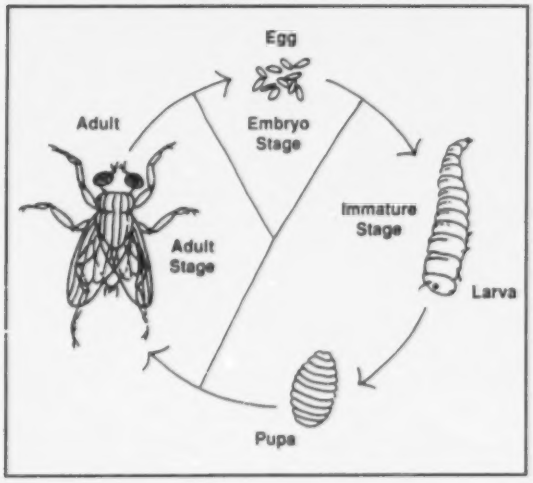
Figure 3.5 - Examples of Wings



Life Stages of Insects

The development of insects refers to growth in size and changes in form. There are three stages of development for every insect: the embryo stage, the immature stage, and the adult stage. See Figure 3.6. Insects begin life as an egg.

Figure 3.6 - Life Stages



Insects may lay from a few to many thousand eggs at a time. The insect lives as an embryo within the egg. The egg is well supplied with a nutritious yolk and surrounded by a delicate outer shell. It may take days, weeks, or months for the insect to hatch. After hatching, the little insect continues to feed and grow through several more stages until it reaches the adult stage.

After the insect hatches, it is called an **immature**. The life of an immature insect is divided into growth stages called **instars**. During each instar, the insect changes in form and size. As the insect grows, it forms an outer layer to protect its body from the environment. This layer is hard and rigid. When the insect grows too big to continue living in this hard layer, it begins to break out of it. The old layer is shed and a new outer layer is formed. The process of shedding the old layer is called **molting**. The most dramatic changes in the growth and form of an insect are seen when the insect molts.

Insects go through a series of instar growth, molting, instar growth, molting, etc. This continues until it becomes an adult insect. The entire process of development is called **metamorphosis**. Most insects go through one of two basic types of metamorphosis, incomplete and complete. There are a few primitive species of insects that do not go through metamorphosis at all.

Incomplete metamorphosis is the first type of insect development. See Figure 3.7. The immature insects look like the adults, only smaller. The immatures of incomplete metamorphoses are called **nymphs**. The changes are mainly an increase in size and the development of wings and sexual organs. Nymphs usually eat the same type of food as the adults. Examples of insects having incomplete metamorphoses are the grasshopper, thrip, stink bug, leafhopper, and aphid.

The second type of insect development is complete metamorphosis. See Figure 3.8. These insects do not look like the adults when in the immature stage. The immatures of complete metamorphoses are called **larvae**. Larvae are small, white forms that do not have eyes or legs. They do have a head and mouth parts. Examples

Figure 3.7 - Incomplete Metamorphosis

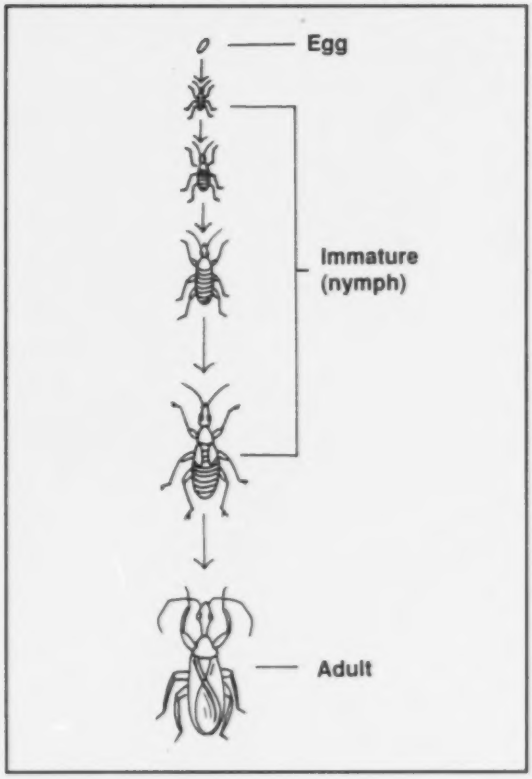
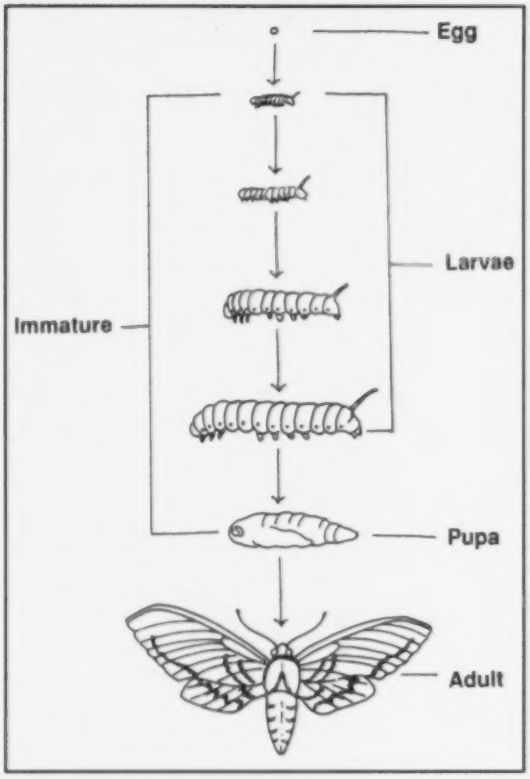


Figure 3.8 - Complete Metamorphosis



of insects having complete metamorphoses are the lady beetle, weevil, fly, and moth. Insects with complete metamorphoses have also one additional stage of development called the **pupa**. When the larva becomes mature, it sheds its skin (or molts) one more time and emerges as a pupa. The pupa is shaped like an insect with the legs and antennae folded against its body. The larvae of some insects surround themselves with a cocoon just before they molt and emerge as pupas.

Although it does not eat and barely moves, great changes take place in the body of the pupa. Most of the structural changes take place during the pupa stage. The adult's digestive system and reproductive system are fully formed. The adult's wings, legs, antennae, and mouth parts develop completely. When the adult's body is completely formed, the insect breaks out of the outer, pupal skin. If there is one, the cocoon is left at the same time. Other insects may help the young one break out.

When the insect first emerges as an adult, the wings are crumpled and the body is soft. Within minutes to hours, the adult's body dries, hardens, and develops color. The wings expand as air blows between them and their structure becomes more rigid. The adult starts its normal life. Depending on the species, adults may live from 1 hour to 20 years. In general, adults live only a few weeks.

Insect Classification

In order to identify each type of animal, the animal kingdom is divided into many groups. Insects belong to one of the basic divisions of the animal kingdom called **Arthropoda**. This division also includes centipedes, crabs, lobsters, scorpions, and spiders. Arthropoda is divided into several **classes**. Insects make up the class **Insecta**. Insecta is a Latin word that can be broken down into its basic meanings: in = "into" and sect = "cut." An insect is identified by its segmented body. This class is further divided

into **orders** of insects. The different orders are determined by certain characteristics, such as wing structure, mouth parts, and life cycle. Presently, entomologists agree on 29 orders of insects.

Orders are further divided and sub-divided into other groups. Each of these groups becomes more and more specific until, at last, each insect species can be identified by its own name. See Figure 3.9.

Figure 3.9 - Insect Classification

Phylum - Arthropoda
Class - Insecta
Subclass - Pterygota
Infraclass - Neoptera
Series - Exopterygota
Superorder - Orthopterodea
Order - Orthoptera
Suborder - Caelifera
Family - Acrididae
Subfamily - Romaleinae
Genus - Romalea
Species - microptera

Scientific name: Romalea microptera
Common name: Eastern lubber grasshopper

Each insect is identified by a scientific name. This name has two parts: the **genus** name (written capitalized) followed by the **species** name (written lower case). The genus is like a person's last name, or family name. The species is like a person's first name. Insects may also have common names. Insects' common names would be like nicknames. For example, a person may have his name listed as "Doe, Jonathan," but his friends call him Johnny. An insect may have the scientific name "Romalea microptera," but is commonly called a grasshopper. When learning scientific names, it is very helpful to find out what the name means. This often gives a clue to some part of the insect's life and makes it easier to remember.

It is impossible to memorize all the insects and their classification. Books such as field guides or insect keys should be kept close at hand and referred to often. Insect guides contain information such as a description of the insect, distinguishing features of the order, how different insects are related to one another, and the lifestyle and environment of the insect. Each guide is a little different so the introduction on how to use the book should always be read first. Beginners are advised to select a guide that has many clear pictures or drawings. The various parts of the insects should be clearly identified and labeled.

The 29 orders and a brief description of each are summarized in the following paragraphs. The summaries include the scientific name, the meaning of the name, the common name, the number of species in each order, the type of metamorphosis, the type of mouth parts, and the main characteristics that distinguish each order.

The Insect Orders

1. **Collembola** * *"glue peg"* * springtails * 1,500 species * no metamorphosis * chewing mouth parts, withdrawn into head * wingless; long antennae; reduced compound eyes or none; most species can jump using a forked springing organ on the abdomen

2. **Protura** * *"first tail"* * Proturans * 170 species * no metamorphosis * piercing-sucking or chewing mouth parts, withdrawn into head * wingless; no eyes; only insects with no antennae; front legs carried upright like antennae and used to sense touch

3. **Diplura** * *"double tail"* * campodeids, japygids * 660 species * no metamorphosis * chewing mouth parts, withdrawn into head * wingless; long, slender antennae; no eyes or small eyes shaped like a slit

4. **Thysanura** * *"tassel tail"* * bristletails, silver fish * 350 species * no metamorphosis * chewing mouth parts * wingless; long, slender antennae; compound eyes reduced or absent; usually scaly body; two or three bristlelike tails; run swiftly or jump when disturbed

5. **Ephemeroptera** * *"short-lived, wings"* * mayflies * 1,000 species * incomplete

metamorphosis * chewing mouth parts * usually two pairs of membranous wings that are held flat over body when at rest, hind wings much smaller than front wings; very short antennae; large eyes; two or three long tails; adults do not eat and die soon

6. **Odonata** * *"toothed"* * damselflies, dragonflies * 5,000 species * incomplete metamorphosis * chewing mouth parts * two pairs of equal-sized, transparent, and membranous wings that cannot be folded; very small antennae; huge eyes; strong fliers; cannot walk, but legs used to catch prey in air; mate in flight

7. **Dermaptera** * *"skin wings"* * earwigs * 1,200 species * incomplete metamorphosis * chewing mouth parts * wingless or two pairs of wings: front wings short and leathery, hind wings large and membranous, folded under front wings when at rest; forceps on abdomen

8. **Grylloblattodea** * *"cricket cockroach"* * rock crawlers, icebugs * 12 species * incomplete metamorphosis * chewing mouth parts * wingless; legs adapted for running; small eyes are long and segmented; antennae are long; live in low-temperature places; active at night; rare

9. **Isoptera** * *"equal wings"* * termites * 2,000 species * incomplete metamorphosis * chewing mouth parts * two pairs of similar, membranous wings held flat over the body when at rest; wings shed after mating flight; workers and soldiers are wingless

10. **Dictyoptera** * *"net wings"* * cockroaches and mantids * 5,300 species * incomplete metamorphosis * chewing mouth parts * front wings are thick and hind wings are membranous and folded; have short wings or are wingless, fly poorly

11. **Phasmida** * *"phantom"* * walking stick or leaf * 2,000 species * incomplete metamorphosis * chewing mouth parts * slow-moving; some are wingless and look like sticks; wings and legs of others look like broad leaves; can change color

12. **Orthoptera** * *"straight wings"* * crickets, locusts, grasshoppers * 20,000 species * incomplete metamorphosis * chewing mouth parts * two pairs of wings: front wings narrow and leathery, hind wings are broad and membranous and folded under front wings when at rest; medium to long antennae; some species wingless; some species make shrill creaking sounds by rubbing special body structures together

13. **Embioptera** * *"lively wings"* * web spinners * 140 species * incomplete metamorphosis * chewing mouth parts * females and some males are wingless, most males have two pairs of membranous wings; front legs have organs for spinning silk

14. **Plecoptera** * *"pleated wings"* * stone flies * 1,300 species * incomplete metamorphosis * chewing mouth parts * two pairs of membranous wings: folded flat over body when at rest, hind wings larger than front wings; long antennae; small eyes

15. **Zoraptera** * *"pure, wingless"* * zorapterans * 16 species * incomplete metamorphosis * chewing mouth parts * have four wings or are wingless: wings have few veins, adults break off wings; compound eyes and small eyes; thread-like, segmented antennae; rare

16. **Psocoptera** * *"gnawing wings"* * bark lice, book lice * 1,700 species * incomplete metamorphosis * piercing-sucking mouth parts * two pairs of membranous wings: roofed over back when at rest, front wings larger than hind wings, some species are wingless

17. **Mallophaga** * *"to eat wool"* * chewing lice * 2,675 species * incomplete metamorphosis * chewing mouth parts * wingless; have reduced eyes or no eyes; parasites of birds and a few mammals, feed on feathers, hair, and skin

18. **Anoplura** * *"unarmed tail"* * sucking lice * 2,900 species * incomplete metamorphosis * piercing-sucking mouth parts * wingless; short antennae; have reduced eyes or no

eyes; parasites that suck the blood of mammals

19. **Thysanoptera** * *"fringe wings"* * thrips * 4,500 species * incomplete or complete metamorphosis * chewing mouth parts * two pairs of wings fringed with long hairs and fold flat over body when at rest, some species are wingless; short antennae; females of many species can reproduce without mating; males are unknown in some species

20. **Hemiptera** * 20.a *"half wings"* * true bugs, chinch bugs * 28,000 species * incomplete metamorphosis * piercing-sucking mouth parts * two pairs of wings: bases of front wings are thick and leathery, hind wings are membranous and fold under front wings when at rest, some species are wingless
20.b. Homoptera * *"same wings"* * aphids, cicadas * 32,000 species * incomplete or complete metamorphosis * chewing mouth parts * wingless or one or two pairs of membranous wings, roofed over body when at rest; females of some species can reproduce without mating

21. **Neuroptera** * *"nerve wings"* * ant lions, lacewings, alderflies and dobson flies * 4,500 species * complete metamorphosis * piercing-sucking mouth parts, sucking parts are shaped like a coiled tube when not in use * two pairs of wings: similar, membranous, covered with many veins, and roofed over body when at rest; long, slender antennae; larvae and adults are predatory

22. **Coleoptera** * *"sheath wings"* * beetles * 350,000 species * complete metamorphosis * chewing or chewing-lapping mouth parts * two pairs of wings: front wings modified into thick, horny wing covers, hind wings membranous and fold under the front wings when at rest, some species are wingless

23. **Strepsiptera** * *"twisted wings"* * strepsipterans * 300 species * complete metamorphosis * piercing-sucking mouth parts * males have one pair of membranous hind wings, front wings are reduced to clublike parts; females do not have antennae, eyes, wings, or legs; they live in other insects

24. **Mecoptera** * *"long wings"* * scorpion flies * 300 species * complete metamorphosis * reduced chewing mouth parts * two pairs of long, slender, and membranous wings, laid flat or roofed over the body when at rest, some species are wingless; long, slender antennae; large eyes; long legs; tip of abdomen of some males are curved like a scorpion's tail

25. **Siphonaptera** * *"tube, wingless"* * fleas * 1,000 species * complete metamorphosis * reduced chewing mouth parts * wingless; body flattened from side to side; simple or no eyes; long hind legs for jumping; parasites that suck blood of birds and mammals

26. **Diptera** * *"two wings"* * flies, mosquitoes * 70,000 species * complete metamorphosis * chewing mouth parts * front wings transparent, hind wings replaced by short, knobbed structures; large eyes

27. **Trichoptera** * *"hair wings"* * caddis flies * 3,000 species * complete metamorphosis * piercing-sucking or sponging mouth parts * two pairs of hairy, membranous wings, roofed over the body when at rest; long antennae; larvae live in cases of silk and debris near or on water; adults eat little

28. **Lepidoptera** * *"scale wings"* * butterflies, moths * 165,000 species * complete metamorphosis * piercing-sucking mouth parts * two pairs of scaly, usually broad, wings, front wings are usually larger than hind wings; long antennae; large eyes

29. **Hymenoptera** * *"membrane wings"* * ants, bees, wasps * 110,000 species * complete metamorphosis * chewing or chewing-sucking mouth parts * two pairs of wings: small, stiff, and membranous, interlock during flight, front wings are larger than hind wings, worker ants and a few other insects are wingless

Summary

Insects are identified and classified according to common characteristics. Features commonly

used are the wings, body shape, mouth parts, and type of metamorphosis. Insects are grouped into 29 orders based on these characteristics. Insect identification guides or keys are very helpful references. They contain a systematic way of finding a great variety of information on many types of insects.

Credits

Bland, R.G. How to Know the Insects. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Borror, D.J. and R.E. White. A Field Guide to the Insects. Boston, MA: Houghton Mifflin Company, 1970.

Evans, Howard E. INSECT BIOLOGY: A Textbook of Entomology. Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

The Random House Encyclopedia. New York, NY: Random House, Inc., 1977.

Control Methods

Insects can be controlled by several different methods. Each of these methods has its own advantages and disadvantages. The methods are grouped as biological control methods, cultural control methods, physical and mechanical control methods, and chemical control methods. Usually, an effective insect control program uses a combination of the methods, depending on the needs of the individual.

Biological Control

The biological control of pests is the oldest control method available. All creatures in nature have natural enemies that repel, kill, and consume them. If these natural enemies were not here, the world would be overrun with insects. Biological control is the use of naturally occurring bacteria, diseases, fungi, viruses, insects, nematodes, birds, fish, toads and frogs, lizards, snakes, rodents, weeds, and others to control insects.

These methods require that the individual has an extensive knowledge about the insect's life cycle, habitat, and response to environmental conditions. Individual insect types cannot be selectively controlled. Biological control requires a lot of time to become effective and then may be only partially effective. It also requires a knowledge of how the environment will be effected by any particular method. The effects on the environment cannot be very well predicted. Although not all biological control methods are costly, they can be very expensive and labor intensive. At this time, these methods are not practical for commercial agriculture. There are four general areas of biological control.

Natural enemies of the insect - This involves selectively increasing the population of the enemies that destroy a particular insect. Insects, such as the ladybug and the praying mantis, are valued because they prey upon a variety of insects that are considered harmful to producers. This method can also involve releasing a virus or disease that infects and kills a particular insect.

Resistant plant varieties - Plant varieties resistant to insect attacks are developed both in nature and through research programs. These host plants are resistant to insects and diseases.

Crop rotations - Crop rotation is an effective biological control method that is used against certain insects. It involves rotating the type of crop grown in a particular spot so that the same crop is not grown year after year. By changing the host species and the environment, insects are less able to build up their populations. Crop rotation is especially effective where insects are not very mobile. This method works because it disrupts the life cycle of the insect and the alternate crop is not suitable for the insect's growth and development.

Sterilization - Radiation or chemicals can be used to sterilize or to genetically alter insects so that they cannot reproduce. These insects can be released into the environment. The particular insect population is then reduced, because it cannot reproduce. This method seems promising but is not yet practical for normal field conditions.

Cultural Control

Cultural control is the management of insect populations by modifying the environment. A thorough knowledge of the insect's life cycle, habitat, and response to the environment is essential for these practices to be successful. Usually, the goal is to make the environment less attractive or agreeable for insects by using standard agricultural practices. These methods are based on disrupting the physical conditions that favor insect life. It is essential to know which conditions to disturb and when to disturb them.

Cultural control methods are only partially effective and individual insect types cannot be selected out. These methods do not require special machinery or equipment and most are not labor intensive. Common cultural methods include tillage, crop rotation, sanitation, timing of harvesting and planting, and water management.

Tillage - How the soil is prepared affects the temperature, moisture, and physical conditions of the soil. Insects may be killed directly by tillage or indirectly. Insects brought to the surface are unprotected and can easily die due to exposure or from being eaten. Often, immature insects living in the soil are killed before they can complete their life cycle.

Crop rotation - This is considered a means of cultural control as well as biological control.

Sanitation - This means removing weeds or crop residues where insects might live. Weeds may attract insects that spread to crop plants. Also, weeds and crop residues may keep insects alive between crop plantings. Plowing under or shredding weeds and crop residues can reduce many insect problems.

Timing of harvest and planting - Insects may be active in large numbers only for a brief period of the season. If it is possible, time the planting and harvesting of crops so that crops are not growing when insects are most active.

Water management - Many insects depend on water or soil moisture for proper growth and development. Regulating water sources can help control insects.

Physical and Mechanical Control

The goal of physical and mechanical control methods is to destroy insects directly or to modify the environment so that it is unsuitable for insect pests. Physical methods destroy insects by using the physical properties of the environment. Mechanical methods require machinery or manual operations to destroy insects. Often these methods are used together. These methods are different from cultural methods because special equipment or operations are used in addition to regular agricultural practices.

Physical and mechanical methods can give immediate and noticeable results. However, they may be expensive and labor intensive. Also, they are only partially effective. There is limited application in commercial agriculture and large field operations. A good knowledge of the insect's life cycle and habitat is necessary when using these techniques. Determining the type of physical and mechanical control methods that can be used depends on how an insect responds to temperature, humidity, odors, and light. Physical and mechanical control methods include cold storage of fruits and vegetables, applying heat, flooding insects out with a wash, treating agricultural products with protective gases, burning crop stubble and field edges, and insect traps used with an attractant (such as roach motels, or insect sticky strips).

Chemical Control

Chemical control primarily involves the use of insecticides. Chemical insecticides work very quickly and effectively. Insect control can be managed better with chemicals than any of the other methods. Insecticides can be extremely dangerous to people, animals, and the environment, if they are not applied properly. They may destroy beneficial insects as well as harmful ones, but it is possible to control a particular insect without harming other beneficial insects, humans, plants, or animals. Some harmful insects develop a resistance to insecticides after a few generations, thus causing the insecticide to be useless in their control. Only a general knowledge of the insect's life cycle, habitat, and response to the environment is needed. Chemical control is usually not labor intensive. Chemical insecticides are usually classified by how they are made. The main groups are known as organic, inorganic, botanical, and bacterial.

Organic - These are manufactured materials that consist mainly of carbon, hydrogen, and oxygen. They are the most widely used type. Numerous organics are available. Organic insecticides are classified in three groups.

1. Chlorinated Hydrocarbon - These insecticides, which are also called organic chlorines, are considered long-lasting, because once they are used they affect living things for several years. They do not break down easily in the environment. Examples are DDT, chlordane, and lindane. Chlorinated Hydrocarbon is slowly being replaced by other kinds.
2. Organic Phosphate - These insecticides contain phosphorus. They can be used on food crops because they do not leave harmful deposits on or in foods. They must be handled carefully because they are highly poisonous to man. Parathion® and malathion® are examples.
3. Carbamate - Carbamates contain groups of nitrogen and hydrogen and can be used to kill most insects. They do not

leave harmful deposits on food, but some are harmful to warm-blooded animals. Aldicarb®, bendiocarb®, carbaryl®, and carofuran® are examples.

Inorganic - These are usually made from minerals. Many inorganics are used to protect cotton, fruit trees, vegetables, and livestock. Since several of these do not break down easily in the environment, they are being replaced by substances that break down more quickly. Lead, arsenate, boric acid, and sulfur powder are examples of inorganic insecticides.

Botanical - These are made from plants. Plant parts are processed and used as either the active killing ingredient or as an attractant. Nicotine, potenome, and dried pyrethrum flowers are examples.

Bacterial - Bacteria are used to infect insects with diseases. Most insecticides work on a ge[illegible] class of insects, whereas a bacterial insecticide specifically kills one kind of insect. They are used on Japanese beetles and caterpillars.

Summary

Insect control is very important in our society. There are several different methods for controlling insects. These control methods are classed as biological, cultural, chemical, and physical and mechanical. Each of these methods has its own advantages and limitations. Usually, an effective insect control program uses a combination of the methods, depending on the needs of the individual.

Credits

Evans, Howard E. INSECT BIOLOGY: A Textbook of Entomology. Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington DC: United States Department of Agriculture. U.S. Government Printing Office, 1982.

Insect Control Recommendations. University of Missouri-Columbia: University Extension, 1990.

The Random House Encyclopedia. New York, NY: Random House, Inc., 1977.

This lesson will focus on chemical insect control. The purpose of insect control is to reduce the damage that can result from insect pest activity. Most producers want a level of control that is effective as well as economical. Chemical control is the most widely used type of insect control because it is direct, very effective, target specific, usually economical, practical for commercial production, and easy to buy and apply.

Pesticides

The term pesticide is a general term for any chemical used to kill any pest. These chemicals are designed to kill, control, or prevent pests from causing damage. A pest can be any living thing that competes with humans for food and fiber, or that attacks people directly. Insecticides are pesticides that are specifically made for controlling insects.

When is an insect considered a pest?

Insects are considered pests when they compete with humans for food and fiber, or attack people directly. Insects are pests when they feed on leaves; tunnel or bore in stems, stalks, and branches; feed on and tunnel in roots; suck the sap from leaves, stems, roots, fruits, and flowers; carry plant and animal diseases or disease agents; feed on and/or feed in seeds and nuts; and feed on and/or feed in humans and animals.

Table 5.1 - Pesticides and Target Pests

Type of Pesticide	Target Pest
Acaricide	mites, ticks
Avicide	birds
Bactericide	bacteria
Fungicide	fungi
Herbicide	weeds
Insecticide	insects
Miticide	mites
Molluscicide	snails, slugs
Nematicide	nematodes
Piscicide	fish
Rodenticide	rodents (rats, mice)

Pesticide Types

Pesticides are classified by the types of pests they are designed to control. The pest for which a pesticide is intended is called the **target pest**. The most common classes of pesticides and their target pests are given in Table 5.1.

Any type of pesticide may effectively control pests other than the desired target group. Most pesticides can kill organisms that are biologically similar to the target pest as well as the target pest. For example, insecticides may kill beneficial insects as well as pest insects.

Mode of Action

Pesticides function in different ways. Attractants attract pests. Repellents keep pests away. Dessicants and defoliants remove or kill leaves and stems. Plant growth regulators stop, speed up, or otherwise change normal plant processes. How a pesticide works is called the **mode of action**. Common modes of action for insecticides are given below.

Contacts - Once an insect comes into contact with a contact poison, it dies.

Systemics - Systemics are applied to the animal or plant on which the insects are feeding. Once the insects feed on the treated host, they die.

Fumigants - Fumigants are gases that kill when they are inhaled or otherwise absorbed by the insect.

Protectants - Once applied to plants, animals, structures, and/or products, protectants prevent entry or damage by insects.

Sterilants - Sterilants make insects unable to reproduce.

Selective insecticides - Selective insecticides kill a particular type of insect without harming other insects.

Nonselective insecticides - Nonselective insecticides kill any insects present.

Growth regulators - Growth regulators prevent immature insects from reaching adulthood.

Biologicals - Living micro-organisms, such as viruses, bacteria, and fungi, are applied to a host to cause a disease in the insect feeding on that host.

Methods of Insecticide Application

The key to using insecticides effectively without injuring plants, animals, or agricultural products is to FOLLOW THE DIRECTIONS ON THE LABEL. Do not use any insecticide product for any purpose for which it is not specified. The methods of insecticide application are described by special terms.

Pre-emergence - Insecticide is applied before crops or weeds emerge.

Preplant - Insecticide is applied before the crop is planted.

Band - Insecticide is applied to a strip over or along each crop row.

Broadcast - Insecticide is applied uniformly to an entire, specific area.

Dip - Dip refers to the complete or partial immersion of a plant, animal, or object in an insecticide.

Directed - In directed application, the insecticide is aimed at a portion of a plant, animal, or structure.

Drench - Drench can mean saturating the soil with an insecticide or the oral treatment of an animal with a liquid insecticide.

Foliar - Foliar refers to applying insecticide to the leaves of plants.

In-furrow - Applying insecticide to or in the furrow in which a plant is planted is the in-furrow application technique.

Over-the-top - Insecticide is applied over the top of a growing crop.

Pour-on - Insecticide is poured along the midline of the back of livestock.

Sidedress - Insecticide is applied along the side of a crop row.

Soil incorporation - Insecticide is applied and incorporated into the soil using tillage implements.

Spot treatment - Spot treatment means to apply insecticide to a small area.

Insecticide Formulations

An insecticide formulation refers to the specific way the product is made. Insecticide formulations have two parts: 1) the active ingredient, which is the chemical that does the work and 2) the inert, or inactive, ingredients, which are the materials that make the active ingredient easier to apply.

There are several common formulations. They are usually made and applied as a liquid, gas, or solid. Each of these has a specific letter abbreviation, frequently used on labels and in recommendations.

Liquid formulations - An emulsifiable concentrate (EC or E) can be mixed with water to form an emulsion in a spray tank. An emulsion is a mixture in which one liquid is suspended as tiny drops in another liquid (such as oil in water). A flowable (F or L) can be mixed with water to form a suspension in a spray tank. A suspension is made by mixing finely divided solid particles in a liquid. A solution (S) is a mixture of one or more substances that are completely dissolved. These ready-to-use formulations are often used on livestock and in barns.

Ultra-low-volume solutions (ULV) are formulations that may contain only the active ingredient itself. They require special application equipment. Aerosols (A) are low concentrate solutions, which are usually applied as a fine spray or mist indoors. Some come in pressurized cans. Liquified gases are fumigant formulations that turn into a gas when applied. Some have to be packaged in pressurized containers.

Dry formulations - Dusts (D) are made by adding the active ingredient to a fine inactive powder. Dusts must be used dry. Granules (G) are made by adding the active ingredient to coarse particles, or granules, of some inactive material.

Granule particles are much larger than dust particles. Soluble powders (SP) are made from an active ingredient that dissolves when added to water. Wettable powders (WP or W) are made by combining the active ingredient with a fine powder and a wetting agent. A wetting agent is a chemical that causes a liquid to cover a surface more thoroughly. Wettable powders look like dusts, but they are made to be mixed with water. Wettable powders need continuous agitation to maintain in suspension. Baits (B) are made by adding the active ingredient to a substance that attracts insects or is eaten by insects.

The following should be considered when selecting the insecticide formulations for a given job:

1. Life cycle and habitat of the insect
2. Type and density of plants
3. Type of coverage needed
4. Type and condition of the target plant or animal
5. Type of insecticide
6. Formulation
7. Weather conditions
8. Equipment used
9. Cost of the insecticide product
10. Best and safest method of control

Applying Insecticides

Weather conditions play an important part in using insecticides. Although some air movement is helpful, it is not wise to spray in winds. Winds can cause an insecticide dust or spray to be unevenly distributed on the plants and to drift away from target areas. Be cautious about spraying if rain is predicted. The effectiveness of an insecticide treatment may be reduced if rain falls soon after spraying. Cold weather may have the same effect. Check the label for any precautions concerning the weather.

The equipment used to apply an insecticide is very important to the success of the insect control job.

The type of application equipment selected depends on the insecticide formulation. Insecticides may be sprayed, dusted, used in a dipping tank, injected, or mixed with insect food. Liquids are generally applied using some kind of sprayer. Sprayers are chosen according to the size of the area being sprayed and the insecticide formulation. There are several sprayer types.

Hand sprayers - Hand sprayers are best for small jobs around the home or farm. They can be used in restricted areas where a power sprayer is not suitable. They are economical, simple, and easy to use, clean, and store. However, hand sprayers may give an uneven application rate because of hand operation. They do not usually have the agitation and screening needed for wettable powder formulations. They must be shaken often to provide agitation.

Low-pressure field sprayers - These sprayers are usually used for treating field and forage crops, pastures, and fence rows. They are also used to apply fertilizer-pesticide mixtures. These sprayers are equipped with medium to large tanks. This sprayer is more versatile and flexible than the hand sprayer. It can be operated at a low cost. A high volume of insecticide is usually needed to make the most effective use of these sprayers. Low pressure will limit penetration. Agitation is also limited.

High-pressure sprayers - High-pressure sprayers are also called hydraulic sprayers. They are designed to handle high volumes (100 or more gallons per acre) at high pressure (above 100 psi). They are usually used on fruits, vegetables, landscape plants, and livestock. These sprayers are well built for extended use. Mechanical agitation keeps the insecticide mixed. They are expensive to operate because large amounts of water, power, and fuel are needed. With high pressure, the spray drifts easily.

Air-blast sprayers - The output from the nozzle is broken up into fine drops by a high-speed airstream. The insecticide moves with the airstream to the target. These sprayers provide good coverage and penetration. Only low pump pressure is required. They usually have mechanical agitation. The sprayer may be difficult to control in small areas. If not properly operated, they may cause an over application of insecticide.

Ultra-low-volume (ULV) Sprayers - These sprayers deliver special ultra-low-volume insecticide formulations. High-speed airstreams are used to break up and direct the spray. No water is

needed for these sprayers and less insecticide is used. Since no water is used during application, there is a danger of an over application. Care must be taken when applying high-concentration insecticides. Few insecticides can be sprayed this way.

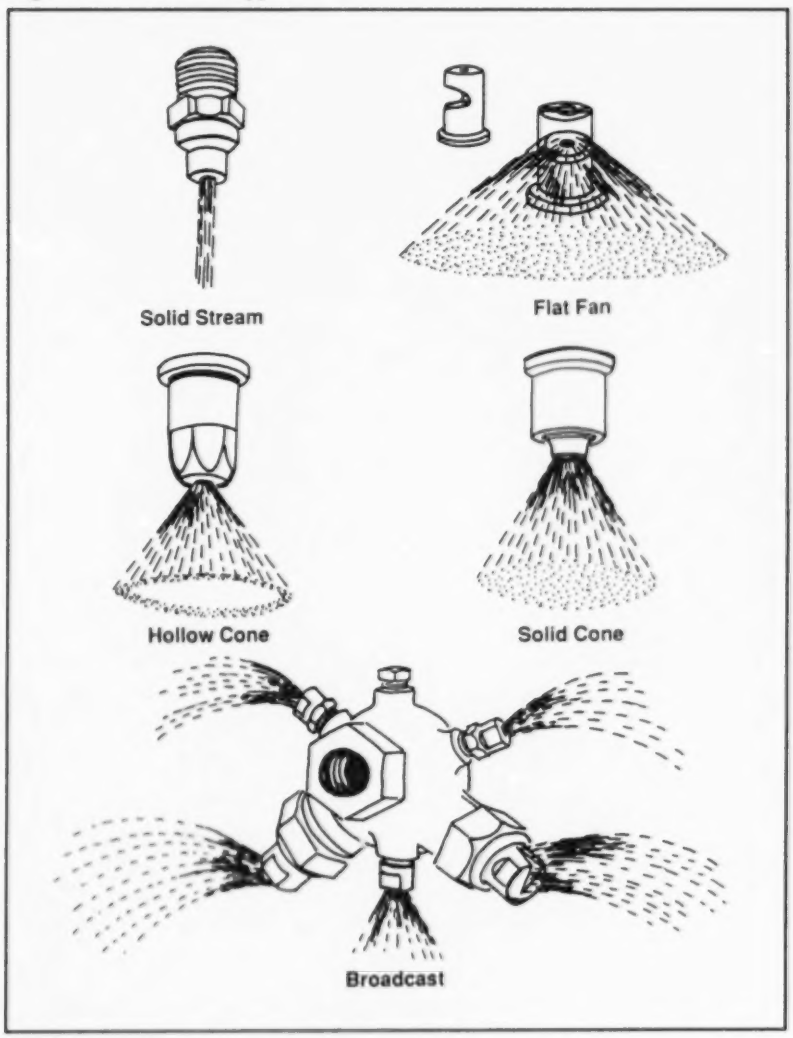
There are five basic nozzle types. See Figure 5.1. Each of these has a special spray pattern. The type of nozzle selected depends on the type of job.

Solid stream - A solid stream is used in handguns to spray a distant target. It is also fixed in a nozzle body to apply a narrow band or to inject it into the soil. There is little drift with these types.

Flat fan - There are different kinds of flat fan nozzles. The regular flat fan nozzle makes a narrow oval pattern with lighter edges. It is used on booms for broadcast spraying. The nozzles are mounted on the boom so that the spray overlaps 30-50 percent for even distribution.

Solid cone - The solid cone nozzle forms a circular pattern. The spray is well-distributed throughout the pattern. It is used for spraying insecticides at high pressures and flow rates.

Figure 5.1 - Nozzle Types



Hollow cone - This nozzle forms a circular pattern with tapered edges. Little or no spray is in the center. It is used for spraying foliage. There are two types of hollow cone nozzles: the core and disk nozzle and the whirl chamber nozzle.

Broadcast - This nozzle forms a wide "flat fan" pattern. It is used on sprayers with or without a boom. When attached to the end of a boom, it expands the width of the area sprayed. This provides good coverage for a wide pattern.

Nozzles are made of brass, stainless steel, plastic, aluminum, tungsten carbide, and ceramic. Each type has advantages and limitations.

Sprayer Calibration

For all spraying applications, there are some standard procedures that should always be followed. Always read the operator's manual supplied by the manufacturer. Choose the speed, pumping pressure, and nozzles that you want to use. For thorough and accurate coverage, the insecticide must be applied evenly and

accurately. To do this, the sprayer must move at a constant speed when in use. The insecticide must be pumping out at a constant pressure. Each nozzle in the system must deliver the correct amount of insecticide. The nozzles must be of the correct type and size. All of the nozzles need to be the same kind. Each nozzle must be clean and mounted at the right height.

Calibrating a sprayer simply means to adjust the equipment so that the desired rate of insecticide can be applied. This is very important to make sure that each insecticide is used as directed on the label. Too much insecticide is dangerous, costly, and wasteful. Too little insecticide will not do an effective job. The best results are safely obtained by calibrating correctly.

There are many ways to calibrate a sprayer. The methods selected will depend on the equipment used and personal preference. Some methods for calibrating standard sprayers are given in Appendix A. Refer to University Extension Guide Sheets for additional information.

Summary

Pesticides are chemicals designed to kill, control, or prevent pests from causing damage. A pest can be any living thing that competes with humans for food and fiber, or that attacks people directly. Selection of a particular insecticide depends on the needs of the producer, the type of insect, the mode of action, and the formulation of the insecticide. There is a variety of sprayers and nozzles available for applying insecticides. Equipment is selected depending on the formulation and application instructions of an individual chemical.

Calibrating a sprayer is very important for safe and effective use of insecticides. It is very important to make sure that each insecticide is used as directed on the label. There are several ways to calibrate a sprayer, depending on the chemical formulation, the equipment used, and the preference of the applicator.

Credits

Apply Pesticides Correctly. Washington, DC: United States Department of Agriculture. U.S. Government Printing Office, 1975.

Boyd, E.M. Toxicity of Pure Foods. Cleveland: CRC Press, 1973.

Greenhouse Operation and Management. University of Missouri-Columbia: Instructional Materials Laboratory, 1990.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington DC: United States Department of Agriculture. U.S. Government Printing Office, 1982.

Guidelines for Insecticide Use. Lexington, KY: University of Kentucky, Department of Entomology, 1989.

Insect Control Recommendations. University of Missouri-Columbia: University Extension, 1990.

Chemical control is a common part of insect management. It is important to know how to work safely with these materials. When using any type of pesticide, it is very important to ALWAYS read and follow label directions exactly. Although the following information applies to any kind of pesticide, this lesson will be referring specifically to insecticides.

The Insecticide Label

The insecticide label contains important information. Always read and follow label directions exactly. It is unlawful to use an insecticide in any manner or for any other purpose than those specified on its label. By reading the label, the individual will be able to determine the type of insecticide being used, the target insects, application techniques, the effects of the product on different plants and insects, the toxicity level, signal words, safety guidelines, disposal methods, and first aid procedures.

Insecticide Toxicity

Insecticide toxicity levels were established by the Federal Insecticide, Fungicide, and Rodenticide Act, also known as FIFRA. FIFRA regulates all stages of pesticide use, manufacture, registration, and transportation. The Missouri Pesticide Act meets these federal guidelines.

LD_{50} - Insecticide toxicity is measured by a standard test called the LD_{50} Test. The "LD" stands for "lethal dose" of a chemical. The lethal dose is determined as the amount of the chemical necessary to kill half (50%) of a test population, such as mice. The LD_{50} is expressed in milligrams per kilogram of body weight. The lower the LD_{50} number, the greater the chemical toxicity and the less it takes to kill. For example, an insecticide with an LD_{50} rating of 5 would be much more poisonous than an insecticide with a LD_{50} rating of 300. On the following page, Table 6.1 shows the oral and dermal LD_{50} values of some common chemicals. For comparison purposes, the LD_{50} values of caffeine, aspirin, and table salt are given. This comparison does not imply that pesticides less toxic than these materials should be used unwisely.

Signal words - Signal words indicate how toxic the chemical is. They are located on the front panel of insecticide labels just below the statement "KEEP OUT OF THE REACH OF CHILDREN." There are three categories of signal words. Class I insecticides are labeled "DANGER" or "DANGER-POISON" with an accompanying drawing of a skull and crossbones. The letters are printed in red. Insecticides in this category are extremely toxic when taken into the body through the mouth, through the skin and/or through breathing. In addition, these insecticides will cause severe eye and skin burning. Insecticides in Class I have an oral LD_{50} rating of 0-50. Some of the Class I insecticides are so highly poisonous that even a taste could kill an adult human.

Class II insecticides are labeled with the signal word "WARNING". Insecticides in this category are moderately poisonous to humans and have an oral LD_{50} rating of 50-500. As little as a teaspoon taken by mouth of some of these pesticides could be deadly. Class III insecticides have the signal word "CAUTION". These insecticides are slightly toxic to humans and have an oral LD_{50} rating or 500-5,000. As little as one ounce of certain of these chemicals taken internally could be fatal.

The insecticide label also contains warning statements such as "fatal if swallowed" or "may irritate eyes, nose, throat, or skin." These warning statements are meant to get your attention, not to indicate the only method of entry for the insecticide. Many insecticides could be harmful to the body if any contact at all is made. It is crucial to wear proper protective clothing whenever applying insecticides.

Pesticide Certification

Applicators may or may not need to be certified in order to handle a particular pesticide. Certification depends on the way the pesticide is used. Pesticides are classified as 100 percent general use, 100 percent restricted use, or a mixture of the two. This information will be clearly stated on the label of the container. A general use pesticide is defined as one not likely to harm people, wildlife, and/or the environment when used according to label instructions. Certification is not required in order to apply general use pesticides. Some examples of these pesticides are Malathion®, Sevin®, and Pyronone®.

Table 6.1 - LD_{50} Values of Chemicals

Chemicals	Oral LD_{50} (mg/kg)	Dermal LD_{50} (mg/kg)
	Organochlorine Insecticides	
aldrin	39	98
chlordane	335	840
heptachlor	100	195
lindane	88	1,000
methoxychlor	5,000	>6,000
strobane	200	>5,000
	Organophosphorus Insecticides	
abate	8,600	>4,000
carbophenothion	30	54
diazinon	108	900
dioxathion	43	235
malathion	1,375	>4,444
parathion	13	21
stirofos	>4,000	2,500
	Carbamate Insecticides	
aldicarb	0.8	3
carbaryl	850	>4,000
carbofuran	8.7	>1,000
mesurol	130	450
zineb	>5,000	>2,500
	Other Insecticides	
binapacryl	63	810
ethylene dibromid	146	300
napthalene	2,200	>2,500
permethrin	4,000	3,000
rotenone	60	>940
	Other Chemicals	
Caffeine	174	-
Aspirin	750	-
Table salt	3,320	-

A restricted use pesticide can cause serious injury to people, wildlife, or the environment. These pesticides must be applied by someone who is well-trained, competent, and certified, or under the direct supervision of a certified pesticide applicator. Certification is required for handling restricted use pesticides. Some examples of these pesticides are Lannate®, Nicotine®, and Thiodan®.

Pesticide certification is given to people who take a special training course set up by the State of Missouri Department of Agriculture. After completing the instructional process, applicants must then pass a test in the safe handling and use of pesticides. Finally, a license is issued to each person who successfully completes the pesticide training session.

There are two types of licenses for certified pesticide applicators: private applicator and commercial applicator. Private applicators administer restricted use pesticides onto their own land, onto land they rent, or onto the property of another person with whom they trade services. A certified private pesticide applicator's license is valid for five years and then must be renewed.

Commercial applicators are hired to apply restricted use pesticides on the property of others. Commercial applicators are trained and tested like private applicators, but receive additional instruction to specialize in various areas. A certified commercial pesticide applicator's license is valid for three years and then must be renewed.

Safety Guidelines For Using Insecticides

Since insecticides may be absorbed through the skin, eyes, and ears, inhaled, and/or swallowed, insecticides must be handled very carefully. First and foremost, always read and follow insecticide label directions exactly. Label directions will not only indicate the application procedures, but the pre-harvest interval and safe re-entry time as well. The pre-harvest interval is the time required between applying the insecticide and the date when the crop can be safely harvested for human consumption. Safe re-entry refers to the time needed between the time an insecticide is applied to an area and the time you need to wait before the area can safely be entered again. Before applying any insecticide, all people, pets, and foodstuffs need to be removed from the area. Never smoke, eat, or drink when applying insecticides.

Protective clothing should always be worn and protective equipment always used to prevent exposure to external irritant insecticides. The following are standard safety clothing and procedures:

1. Wear clean long trousers and a long-sleeved shirt, or coveralls made of closely woven cloth.
2. Wear unlined rubber gloves and rubber boots made of neoprene.
3. Wear shirt sleeves outside of the gloves and wear pant legs outside of the boots to prevent insecticides from entering.
4. Wear close-fitting eye goggles or a face shield.
5. Wear a wide-brimmed waterproof hat, one that is easy to clean or is disposable.
6. Wear a respiratory device that prevents internal poisoning whenever applying an insecticide.
7. Clean clothing and equipment as directed by the insecticide label or by the poison control center recommendations.

Respiratory devices - Insecticides give off fumes and some quickly become gases. This poses a great threat of injury or death by inhalation to insecticide applicators. Respiratory devices cover the mouth and nose and filter the air of harmful substances. Although they are recommended whenever using insecticides, they are especially important when working in confined or closed areas. Be sure that every respirator carries a seal of approval for insecticide use from the National Institute for Occupational Safety and Health (NIOSH) as well as from the Mine Safety and Health Administration (MSHA). Carefully read the accompanying instructions for the use and care of each respirator. There are several different types available depending on the spraying conditions.

1. Cartridge respirator - used for occasional exposure to most insecticides.
2. Gas Mask or Canister Respirator - used when the applicator is exposed to an insecticide for a relatively long period of time or is exposed to high concentrations

of insecticides for a short period of time, and working in a confined or closed area.

3. Self-Contained Breathing Apparatus - used if the oxygen supply is low or the insecticide vapor concentration is high.

Precautions should always be taken to avoid insecticide drift. Insecticide drift occurs when the insecticide tends to drift away from the target area. This can be avoided by always following the label directions, using the proper equipment for the job, and not spraying when it is windy.

After applying insecticides, remove clothing and take a shower with plenty of soapy water; shampoo and rinse the hair well. Wash insecticide exposed clothing separately from other clothing. If disposable clothing is worn, dispose of it properly.

If insecticides are applied on a regular basis, a health watch program should be established with a physician. Inform the doctor about the type of insecticides being used. Then the doctor can review the chemical formulations, poisoning symptoms, and treatments. In addition, the physician can stock a supply of the necessary drugs needed for treatment. Being prepared in case insecticide poisoning occurs is important because there are no drugs to prevent it.

Applicators who work regularly with carbamate or organophosphate insecticides should set up a cholinesterase testing program with their physicians. Cholinesterase is a biological enzyme that is part of the body's nervous system. Carbamate and organophosphate insecticides can cause serious health hazards by interfering with the availability of cholinesterase in the body. Therefore, the doctor should perform a cholinesterase test in January to establish a "base line level" for each applicator. Then periodic re-tests must be taken check cholinesterase levels.

If the applicator's cholinesterase level falls too low, then the doctor will limit or stop the patient's contact with these two types of insecticides.

Disposal of Insecticides and Containers

Always try to mix the correct amount of insecticide solution for each application to avoid the need to dispose of any extra chemical. Any extra insecticide solution must be disposed of safely to avoid harming people, animals, or the environment. The U.S. Department of Agriculture and the U.S. Environmental Protection Agency have set up specific guidelines for insecticide disposal. The State of Missouri Department of Natural Resources can help with questions and problems concerning the safe disposal of insecticides and insecticide containers. The address and phone numbers are as follows:

Missouri Department of Natural Resources
Division of Environmental Quality
P.O. Box 176
Jefferson City, MO 65102
Business phone: (314) 751-7929
Emergency response phone: (314) 634-2436

Carefully read and follow the instructions for precautions and/or disposal methods on the insecticide container label. NEVER flush insecticides down the drain or into sewers. If there are additional areas having the same insect problem, apply the extra insecticide on those areas as well. If this is not possible, then take the excess insecticide and/or insecticide containers to a landfill that has a permit for toxic waste disposal. This should also be done for outdated or unwanted insecticides. Keep in mind that many solid waste landfills do not have this special permit and, therefore, are not legally able to handle insecticides. Federal regulations require that organic insecticides be disposed of by burial or by burning.

Do not leave insecticides or insecticide containers at the place where the chemicals were applied. Never reuse insecticide containers. Keep all insecticide containers out of the reach of children. Any insecticides leftover should be kept in tightly closed containers in a storage facility.

Symptoms of Insecticide Poisoning

Since different insecticides affect people differently, there are no standard symptoms of insecticide poisoning. Symptoms will vary depending on the type of insecticide, amount and length of exposure, the time interval between exposures, and the general health of the victim.

Insecticide poisoning may be divided into external irritants, internal poisons, or a combination of

both. External irritant insecticides may cause swelling, stinging, redness, blisters, and/or rash when splashed on the skin or external body tissues, such as eyes, ears, and mouth. Insecticides causing internal poisoning are dangerous when swallowed, inhaled, or absorbed through the skin. These may cause such symptoms as headache, nausea, vomiting, and diarrhea. Some insecticides can cause both external irritation and internal poisoning at the same time.

Insecticide poisoning symptoms may be similar to symptoms of other illnesses, such as the flu. However, flu medicine should not be used to relieve these symptoms as they may make insecticide poisoning much worse. Therefore, it is important to talk with a doctor who can diagnose the difference and prescribe proper treatment.

First Aid Procedures for Insecticide Poisoning

When you think an insecticide poisoning has occurred, ALWAYS ACT IMMEDIATELY. The amount of time between the insecticide poisoning and getting to the doctor may make the difference between life and death for the poisoning victim. It is extremely important to stay calm and take quick action. Follow these steps:

1. Protect yourself from contamination. Wear protective clothing and/or equipment. You won't be able to assist anyone else if you are not protected yourself.
2. Without endangering yourself, remove the victim from the contaminated area.
3. Remove contaminated clothing from the victim.
4. Flood the affected area with a generous amount of water.
5. Contact the Poison Control Center or a doctor and administer first aid procedures as indicated. Keep the insecticide label handy for reference.

First Aid Kit

First aid supplies should always be near any place where insecticides are handled. The container used for the first aid supplies should keep the supplies clean and be easily accessible.

A first aid kit should contain items such as the following:

1. Adhesive tape
2. Assorted adhesive and gauze bandages
3. Blanket - enclosed in plastic to keep clean and dry
4. Merthiolate
5. Syrup of ipecac
6. Teaspoon
7. Two quarters - taped to the inside cover of the first aid kit for phone calls

Poison Control Center

The local Poison Control Center number should be located by the phone for easy access. In Missouri, the Poison Control Center is staffed 24 hours a day by medical professionals. These professionals will ask questions about the victim and about the insecticide. It is important to have the insecticide label or container close by when contacting the center.

The statewide center may refer calls to a local hospital specifically equipped to treat poisoning emergencies. Information about Missouri's statewide center and its toll-free number are given below.

Missouri Regional Poison Control Center
Cardinal Glennon Memorial Hospital
1465 South Grand Avenue
St. Louis, Missouri 63104
Telephone: 1-800-392-9111

Summary

To avoid toxic chemical injury to humans, animals, and/or the environment, it is crucial to read and follow all label directions for the insecticide being applied. Depending on the insecticides to be applied, the applicator may be required to have a certified pesticide applicator's license.

Appropriate clothing and protective equipment should always be worn when applying insecticides. Insecticides should always be handled with care and disposed of properly.

Credits

Guidelines for Insecticide Use. Lexington, KY: University of Kentucky, Department of Entomology, 1989.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington DC: United States Department of Agriculture. U.S. Government Printing Office, 1982.

Insect Control Recommendations. University of Missouri-Columbia: University Extension, 1990.

Pest Management Strategies in Crop Protection. Washington, DC: Congress of the United States. Office of Technology Assessment.

Agriculturalists are always looking for ways to produce food and fiber with a quality and in the quantity the world wants. Buildings, roads, and other structures need to be safe and to last. Health professionals are always looking for ways to keep humans and animals in good health. And this must usually be done at a profit. The job of the entomologists is to management the huge and diverse insect population so that these goals can be achieved.

IPM

Insect control programs must be developed for each individual situation. There are certain steps which greatly help when developing an insect control program. These steps form an efficient system which is called an **IPM** program. The letters "IPM" are used to refer to two different programs. The general program is called Integrated **P**est **M**anagement. This refers to any pest control program. If the pest in question is specifically insects, then the letters can stand for Insect **P**est **M**anagement.

Why IPM is Important

The basic goal in insect pest management is to prevent insect populations from reaching a level that can cause substantial damage to a crop. This is referred to as the **economic injury level (EIL).** The economic injury level is the amount of damage insects do to a crop that equals the cost it requires to use measures that suppress the insects. Insect suppression measures have different functions. Some are designed to prevent the insect population from increasing. Others work to reduced the population already present. Still others work to prevent a particular insect population from becoming a problem in the first place.

Economic Threshold

It is not always necessary to start insect control measures when insects are seen on a crop. The **economic threshold** is used to determine when insect control measures should be considered. The economic threshold indicates the level of damage done by an insect that is used to warn the agriculturalist of potential problems. To determine when the economic threshold is reached, careful sampling must be done. This may involve counting the actual number of individual insects per unit. Other methods used involve some form of removal, trapping, visual estimates, or assessing the amount of plant damage. When the economic threshold is reached, it is necessary to use methods to keep the insect populations from reaching the economic injury level.

Steps in an IPM Plan

Once it has been determined that insect control measures need to be considered, an IPM plan can be developed. There are specific steps in developing an IPM plan.

Identify the problem - Never try to control a problem until you are sure what it is. Identifying the cause of a plant problem or symptom correctly can be very difficult. There may be many reasons why a plant is not growing properly. For example, plant leaves may turn yellow because of insect attacks, plant diseases, nutrient deficiencies, or herbicide injury. Insects may be the indirect cause of poor plant health. A plant that is already nutrient deficient tends to attract insects. The insects are not the direct cause of the problem, the nutrient deficiency is. Even if the insects are eliminated, the plant would not recover until the nutrient deficiency is corrected.

Identifying the problem incorrectly may cause the wrong method of control to be selected. This not only wastes money but probably will not fix the problem as well. In fact, the real problem will usually get worse. Determining the reason(s) for plant problems in a field environment is often very challenging. It takes an experienced and well-trained individual to find the correct answers.

If an insect problem has been identified, and you know how the insect grows, how it spreads, and what damage it does, you can begin to plan how to control it. Using an insecticide is one of many ways to control pests. The use of a combination of methods is basic to all pest control. Be sure to think about what other methods might work before you decide to apply an insecticide. You can minimize insect problems by:

1. Encouraging the growth of insects' natural enemies
2. Planting crop varieties that resist insects
3. Destroying crop residues
4. Practicing good fertilizer and manure management
5. Good management of the selected tillage system

Assess the damage - In addition to finding the root cause of the problem, it is very important to determine exactly how extensive the damage may be. Plants have a remarkable ability to recover from insect attack. Some injuries are only on the surface. Even though it may look bad, the crop is not damaged to the point of economic losses. For example, a 5 percent or 10 percent leaf loss appears very damaging, but most plants can grow out of it. On the other hand, small insects and soil insects may not be noticed and yet can be responsible for significant plant damage.

The stage of development of the plant and insect is another point to consider. When assessing plant damage, there is no substitute for a knowledgeable person. It can be very expensive and unnecessary to start measures to suppress or contain insects that may not be causing real damage.

Prepare cost/benefit analysis - A cost/benefit analysis can be difficult to do. A cost/benefit analysis means comparing the cost of an insect control plan with the benefits that the control plan will give. The value of the increased crop yield should be equal to, or higher than, the cost of the actions taken to control insects. The benefits include the short-term value of increased crop yield as well as the long-term value of keeping the insect population under control for the rest of the growing season and following years. Often, it is possible to control an insect population by suppressing the first generation. Later in the season, the number of insects may be greater and more difficult to control. You also need to consider what effects control measures may have on beneficial insects. Lowering the beneficial insect population can increase the harmful insect population and increase control costs overall.

Insect control is necessary only when the insect is causing more damage than is reasonable to accept. Even though an insect is present it may not do much harm. It could cost more to control the insect than it would have been lost by insect damage.

Select a management strategy - There are many insect management strategies to choose from. You need to consider the various factors that influence the selection of a plan. These include:

1. Present crop
2. Cropping system
3. Tillage system
4. Life cycle and habitat of the harmful insects
5. Life cycle and habitat of the beneficial insects
6. Kind of damage that the insect causes
7. Type and condition of the plants or animals under attack
8. Time of year
9. Environmental conditions
10. Geographic location
11. Cost of insect control
12. Goals of the producer

The most common strategies are planting pest-resistant crop varieties and applying insecticides. These measures are used because they are effective, easily available, economical, and, in general, can be used easily by anybody. Other strategies include crop rotation, biological control, and modifying the planting time. However, these measures may not be as efficient or effective. They also require a greater knowledge of entomology and pest management.

Implement the management strategy - When selecting a management strategy, a major factor is the ability to actually put it into action and see it through to completion. There are many strategies and alternatives from which to choose. One who is devoted to biological control may be unable to implement it effectively or efficiently. On the other hand, some people are all too ready to employ chemical control exclusively because the materials are readily available. An experienced individual will consider a variety of measures for any particular situation or problem.

Planning is essential for an insect management plan to be successful. Many cultural and biological controls need to be implemented before or during soil preparation and crop planting. For

example, a crop rotation, soil insecticide, or choice of insect resistant seeds needs to be made in advance.

It is not always necessary to plan for the worst. Insect populations can be watched and sampled throughout the growing season. Remember that a few insects does not mean a crisis is at hand. When insect damage is noticed, begin monitoring the damage. Now consider the plant growth, the remaining growing season, the climate, and the insect's life cycle. The insect population may not be causing substantial economic damage, or the crop may not be seriously injured. With this information, an appropriate strategy can be made to determine if control measures are needed at all, and if so, how much should be spent on them.

Follow-up of the plan - Following up on a regular basis is an important part of any insect management program. The effectiveness of the measures selected can be judged only by carefully watching the insect populations and crop growth. This can be done through regular sampling. We cannot assume that an insect problem has been thoroughly controlled just because the control measures have been put into action. Control measures may need to be alternated, modified, increased, or decreased as the growing season progresses. Keeping careful records will give a great deal of information on how well the selected plan is working and how efficient and effective the measures are.

Crop Calendars

Most IPM programs begin by focusing on the crop. From there, other factors are added to give a better perspective on the situation. Making a crop calendar is a good way to evaluate any possible problems and different insect control plans. A crop calendar is an outline of the crop's growing season. It provides a systematic and efficient way of looking at the components in a cropping system. Management decisions are easier to make. The basic steps in developing a crop calendar are given below.

A crop calendar is an outline of the crop's growing season. It provides a systematic and efficient way of looking at the components in a cropping system. See Figure 7.1.

1. Set up a table with the twelve months across the top. The left column will indicate crop information such as the following: crop growth stages, insects (be specific), tillage operations, fertilizer applications, herbicide applications, and harvesting.
2. If different insect stages affect the crop at different times, indicate what stage the insect is in and when it causes damage.
3. Indicate the period when insects are most likely to be present and when populations are most likely to cause economic damage.

Now, look at the table (crop calendar) to see when each particular insect will most likely cause the most damage. Look at the growth stage of the crop at this time and think about the following questions.

1. Is the insect attack happening at a critical time in the growth of the crop?
2. Will the crop be able to grow out of any damage?
3. Can the insect damage be prevented?
4. What insect control measures can be used?
5. What are the advantages and limitations of each of these methods?
6. How much insect control is needed at this time, considering both the growth stage of the crop and the insect's life cycle?
7. How will each of the methods affect the rest of the crop calendar?
8. How much will it cost?
9. When should the selected measures be started?
10. What other factors should be considered in selecting a management plan?

With this information, it is easier to evaluate a potential problem and make a decision. There is no "right" or "wrong" choice in selecting control methods. Each situation is different. Only with practice will an individual become a knowledgeable and experienced insect manager.

Figure 7.1 - Sample Crop Calendar for Corn

Crop Information	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Crop Growth Stages				Seedling	Knee-high	Whorl	Tassel	Silk, Dent, Dough	Maturity			
Insects												
Cutworms				***XXXXXXXXX***								
Corn Flea Beetle				**XXXXXXXXX********								
Corn Leaf Aphid						*******	XXXXXXX***					
Corn Rootworms						larvae	adults					
						**XXXXX	***XXXXXX***	*****				
European Corn Borer			eggs		*XXXX**							
			1st generation larvae			**XXXXXXX***						
			2nd generation larvae				**XXXXX**					
Tillage Operations Fertilizer Applications Herbicide Applications												

* - period when insects are most likely to be present
X - period when populations are most likely to cause economic damage

Summary

There are many factors to consider when developing insect control plans. The individual plan selected will be different for each particular situation.

Crop calendars provide a systematic and efficient way of looking at the components in a cropping system and evaluating different possible control plans.

Credits

Apply Pesticides Correctly. Washington, DC: United States Department of Agriculture. U.S. Government Printing Office, 1975.

Bland, R.G. How to Know the Insects. Dubuque, IA: Wm. C. Brown Company

Insect Control Recommendations. University of Missouri-Columbia: University Extension, 1990.

The Random House Encyclopedia. New York, NY: Random House, Inc., 1977. Publishers, 1978.

These terms are commonly used in entomology and insect control. Some of these words have several meanings. Those given here are the meanings that relate to insect control.

Absorption - The process by which a chemical is taken into plants, animals, or minerals. Compare with adsorption.

Activator - A chemical added to a pesticide to increase its activity.

Adherence - Sticking to a surface.

Adjuvant - Inactive ingredient added to a pesticide formulation to make it work better.

Adsorption - The process by which chemicals are held on the surface of a mineral or soil particle. Compare with absorption.

Aerobic - Living in air. The opposite of anaerobic.

Aerosol - An extremely fine mist or fog consisting of solid or liquid particles suspended in air. Also, certain formulations used to produce a fine mist.

Agitation - The process of stirring or mixing in a sprayer.

Anaerobic - Living in the absence of air. The opposite of aerobic.

Animal Sign - Evidence of the presence of an animal in an area.

Antagonism - The loss of activity of a chemical when exposed to another chemical.

Antibiotic - A substance which is used to control pest microorganisms.

Antidote - A practical treatment for poisoning. This includes first aid.

Aqueous - A term used to indicate the presence of water in a solution.

Aseptic - Free of disease-causing organisms.

Booting - The growth stage of cereal crops when the upper leaf sheath swells due to the growth of developing spike of panicle.

Botanical Pesticide - A pesticide made from plants. Also called plant-derived pesticides.

Broadleaf Weeds - Plants with broad, rounded, or flattened leaves.

Brush Control - Control of woody plants.

Carbamate - A synthetic organic pesticide containing carbon, hydrogen, nitrogen, and sulfur.

Carcinogenic - Capable of causing cancer.

Carrier - The inert liquid or solid material added to an active ingredient to prepare a pesticide formulation.

Causal Organism - The organism that produces a specific disease.

Chemosterilant - A chemical that can prevent reproduction.

Chlorinated Hydrocarbon - A synthetic organic pesticide that contains chlorine, carbon, and hydrogen. Same as organochlorine.

Chlorosis - The yellowing of a plant's green tissue.

Cholinesterase - A chemical catalyst or enzyme found in animals that helps regulate the activity of nerve impulses.

Compatible - When two or more chemicals can be mixed without affecting each other's properties, they are said to be compatible.

Concentration - The amount of active ingredient in a given volume or weight of formulation.

Contaminate - To make impure or to pollute.

Corrosion - The process of wearing away by chemical means.

Deflocculating Agent - A material added to a suspension to prevent settling.

Degradation - The process by which a chemical is reduced to a less complex form.

Dermal - Pertaining to the skin; through the skin.

Dermal Toxicity - Ability of a chemical to cause injury when absorbed through the skin.

Diluent - Any liquid or solid material used to dilute or carry an active ingredient.

Dilute - To make thinner by adding water, another liquid, or a solid.

Dispersing Agent - A material that reduces the attraction between particles.

Dormant - State in which growth of seeds or other plant organs stops temporarily.

Dose, Dosage - Quantity of a pesticide applied.

Emulsifier - A chemical that aids in suspending one liquid in another.

Emulsion - A mixture in which one liquid is suspended as tiny drops in another liquid, such as oil in water.

Fungistat - A chemical that keeps fungi from growing.

GPA - Gallons per acre.

GPM - Gallons per minute.

Hard water - Water containing soluble salts of calcium and magnesium and sometimes iron.

Heading - The growth stage of cereal crops when the seed head is emerging from the upper leaf sheath.

Herbaceous Plant - A plant that does not develop woody tissue.

Host - The living plant or animal a pest depends on for survival.

Immune - Not susceptible to a disease or poison.

Impermeable - Cannot be penetrated. Semipermeable means that some substances can pass through and others cannot.

Jointing - The growth stage of cereal crops when stem internodes begin elongating rapidly.

Larva - The early form of an insect with complete metamorphosis from the time that it leaves the egg until it becomes a pupa.

LC_{50} - The concentration of an active ingredient in air which is expected to cause death in 50 percent of a group of test animals treated with the active ingredient. A means of expressing the toxicity of a compound present in air as dust, mist, gas, or vapor. It is generally expressed as micrograms per liter in the case of a dust or mist and as parts per million (ppm) in the case of a gas or vapor.

LD_{50} - The dose of an active ingredient taken by mouth or absorbed by the skin which is expected to cause death in 50 percent of a group of test animals treated with the active ingredient. If a chemical has an LD_{50} of 10 milligrams per kilogram (mg/kg) it is more toxic than one having an LD_{50} of 100 mg/kg.

Leaching - Movement of a substance downward or out of the soil as the result of water movement.

Mammals - Warm-blooded animals that nourish their young with milk. Their skin is more or less covered with hair.

Metamorphosis - A change in shape, form, and size in insects. A system of insect development.

Miscible Liquids - Two or more liquids that can be mixed and will remain mixed under normal conditions.

MPH - Miles per hour.

Mutagenic - Capable of producing genetic change.

Necrosis - Localized death of living tissue such as the death of a certain area of a leaf.

Necrotic - Showing varying degrees of dead areas or spots.

Nitrophenols - Synthetic organic pesticides containing carbon, hydrogen, nitrogen, and oxygen.

Noxious Weed - A plant defined as being especially undesirable or troublesome.

Nymph - The early form of an insect with incomplete metamorphosis from the time that it leaves the egg until it becomes an adult. They look like the adult but do not have fully developed wings.

Oral - Pertaining to the mouth; through or by the mouth.

Oral Toxicity - Ability of a pesticide to cause injury when taken by mouth.

Organic Compounds - Chemicals that contain carbon.

Organochlorine - Same as chlorinated hydrocarbon.

Organophosphate - A synthetic organic pesticide containing carbon, hydrogen, and phosphorus; two examples are parathion and malathion.

Ovicide - A chemical that destroys eggs.

Parasite - A plant or animal that lives on or in another plant or animal from which it gets food.

Pathogen - Any disease-producing organism.

Penetration - The act of entering or ability to enter.

Pest - Living things that compete with people for food and fiber, or attack people directly.

Phytotoxic - Harmful to plants.

Pollutant - An agent or chemical that makes something impure or dirty.

PPB - Parts per billion. A way to express the concentration of chemicals in foods, plants, and animals. One part per billion equals 1 pound in 5,000 tons.

PPM - Parts per million. A way to express the concentration of chemical in foods, plants, and animals. One part per million equals 1 pound in 500 tons.

Predator - An animal that destroys or eats other animals.

Propellant - Liquid in self-pressurized pesticide products that forces the active ingredient from the container.

PSI - Pounds per square inch.

Pupa - The last stage of an immature before becoming an adult in the development of insects having complete metamorphosis.

RPM - Revolutions per minute.

Safener - A chemical added to a pesticide to keep it from injuring plants.

Seed Protectant - A chemical applied to seeds before planting to protect seeds and new seedlings from diseases and insects.

Soil Sterilant - A chemical that prevents the growth of all plants and animals in the soil. Soil sterilization may be temporary or permanent, depending on the chemical.

Soluble - Will dissolve in a liquid.

Solution - Mixture of one or more substances in which all ingredients are completely dissolved.

Solvent - A liquid which will dissolve a substance to form a solution.

Spreader - A chemical which increases the area that a given volume of liquid will cover on a solid or on another liquid.

Sticker - A material added to a pesticide to increase its adherence.

Surfactant - A chemical which increases the emulsifying, dispersing, spreading, and wetting properties of a pesticide product.

Susceptible - Capable of being diseased or poisoned; not immune.

Susceptible Species - A plant or animal that is poisoned by moderate amounts of a pesticide.

Suspension - Finely divided solid particles mixed in a liquid.

Synergism - The joint action of two or more pesticides that is greater than the sum of their activity when used alone.

Target Pest - The pest at which a particular pesticide or other control method is directed.

Tillering - The growth stage of cereal crops when additional shoots are developing from the flower buds.

Tolerance - 1) The ability of a living thing to withstand adverse conditions, such as pest attacks, weather extremes, or pesticides. 2) The amount of pesticide that may safely remain in or on raw farm products at time of sale.

Toxicant - A poisonous chemical.

Trade Name - Same as a brand name.

Vapor Pressure - The property which causes a chemical to evaporate. The lower the vapor pressure, the more easily it will evaporate.

Vector - A carrier, such as an insect, that transmits a pathogen.

Viscosity - A property of liquids that determines whether they flow readily. Viscosity usually increases when temperature decreases.

Volatile - Evaporates at ordinary temperatures when exposed to air.

Wetting Agent - A chemical that causes a liquid to contact surfaces more thoroughly.